

ALASKA LEGISLATURE SPECIAL COMMITTEE / SUBJECT FILE
1809 SCOMM 74: SEN. SPEC. COMM. ON DOMESTIC & INTL. FISH., 1991-92. 8672

2. Regional v. Statewide Planning.

State law directs salmon production planning to be done on a regional basis. Although the commissioner of ADF&G has overall authority for both PNP and department enhancement efforts, little comprehensive statewide planning is done, with only minimal interaction between regions of the state. Most planning focuses on *production* in a region and not whether the production is *desirable* relative to other regions. Additionally, within each region, state hatcheries have varying interaction with the private enhancement efforts.

Today, however, hatchery produced fish comprise a growing proportion of the statewide harvest. There are concerns that Alaska's production-oriented enhancement program may result in one region's program affecting markets, prices and management in other regions.

Fisheries managers argue that the state needs a statewide planning policy that will take into account the potential impacts of one region on another, as well as closely scrutinizing potential management problems and marketing feasibility.

Others agree with the idea in principle, but maintain that such an effort is impossible in a state where competing interests would find it difficult to agree on a system that diminishes local control over hatchery development and production goals. Shifting to a statewide review could create enormous tensions between the user groups of different regions.

The Board of Directors of the United Fishermen of Alaska (UFA) in January 1992, requested the FRED Division to involve all RPTs in a statewide review process of hatchery production. The request was based on the premise that "[s]ince hatchery production is now at a level that the impacts are no longer confined to one region, UFA believes that such a review is warranted now more than ever."

3. Funding and support for planning.

Fishermen, hatchery operators, and state fisheries managers agree that the RPT planning process provides an important forum for discussing and resolving difficult issues on an ongoing basis.

However, *state support for planning has declined since the early 1980s* when FRED had a budget of over \$500,000 for grants to aquaculture associations. Grants were gradually reduced and eliminated in 1987. Meanwhile, the number of regions requiring plans increased from six in 1987, to ten by the end of 1991. Initial, one-time-only planning grants of up to \$100,000 are still available for regional aquaculture associations from the Department of Commerce and Economic Development.

Despite the need for more rigorous planning because of increased enhanced production, FRED planning staff has declined from two to one and a half positions. These positions coordinate all enhancement efforts statewide, including state facilities, provide technical assistance to the PNPs, and plan new ventures.

Budget reductions have forced state planners to shift priorities from plan development and implementation to plan maintenance. As a result of decreased state support, Prince William Sound and Cook Inlet Aquaculture Associations have hired full time planners. Although hired by the regional associations, these planners consider

themselves staff to the local RPT. However, they are also involved in internal corporate planning, and arguably, this could be considered a conflict.

As a result of budget cuts, new planning efforts are minimal. New ventures are at a distinct disadvantage when compared to those started ten years ago. In the past, there was money for new hatchery projects, either through state general bond initiatives, grants or loans. More recently however, new hatchery initiatives have received little financial support.

FRED managers, gear group representatives and several aquaculture association managers strongly believe that present funding levels for planning are inadequate for FRED to properly oversee the functions of the 37 hatcheries in operation in Alaska. As a result, they believe that many more conflicts and issues will develop that should have been resolved early in the process. Perhaps just as importantly, FRED managers indicate that they are unable to consider the "big picture" issues such as long-term analyses and guidance for future developments.

RPT members also complain that the cutback in funds for planning has limited their contribution to a cursory discussion and approval of permit changes. If a hatchery requests a change in permit, they often have to wait six months or longer to be considered because funds are not available for some RPTs to meet more than twice a year.

4. Composition of Regional Planning Teams

*Although many people believe the regional planning team (RPT) process is a good one if adequately staffed and funded, there are others who believe that the entire structure of the RPT should be changed. A frequent complaint is that the composition of the RPT is heavily weighted towards the commercial sector of the fishing industry, without sufficient representation of subsistence and sport fishing users, community and regional governments, environmentalists, and the general public. There critics argue that in order to have a truly *balanced* decision, all the varied interests of the region need to be adequately represented. Some RPTs have tried to address this complaint by broadening the composition of the team to include all interested groups.*

Another, more fundamental concern is that ADF&G managers are usually out-numbered on the RPTs. As a result, the group can pressure department managers into approving projects that should probably be denied. Department personnel who raise future management concerns are under considerable pressure to be a *positive* presence in the RPT process, which in some cases, translates into withdrawing or modifying their objections without these concerns being adequately addressed. On the other hand, concern has also been expressed that department managers sometimes have a strong, anti-hatchery bias that can influence their management recommendations.

There is also the concern that the non-Fish and Game members of the RPT may not be sufficiently capable of evaluating and making decisions on issues that are increasingly technical in nature.

5. Allocation issues.

While issues such as location, harvest timing and cost recovery projections are scrutinized, the question of allocation is not considered by any of the parties involved with the RPT review process; AS 16.05.251 delegates that responsibility to the Board of Fisheries.

Without the ability to consider allocation issues as part of the permit review process, ADF&G may approve a hatchery permit that could create future allocation problems. By the time the Board of Fisheries begins to consider allocation problems resulting from hatchery production, millions of dollars may have been invested through state loans. The state may well feel a financial obligation to ensure the success of the facility.

In addition, allocation conflicts over hatchery-produced fish may eventually require tagging programs as part of their resolution. The question of tagging -- and who should pay for it -- is one that is more easily addressed early in the planning and permitting process.

Recent developments seem to indicate a change for the future. *In 1988, the Board of Fisheries charged the Prince William Sound Aquaculture Corporation (PWSAC) with development of an allocation plan for enhanced stocks in Prince William Sound.* After an intense planning effort and several drafts, PWSAC was able to come up with an allocation scheme that all user groups and the department could support. The allocation plan was approved by the Board of Fisheries in 1991 and was in effect this past fishing season. The regional planning team incorporated the allocation plan with its production and management plans into a comprehensive Phase III maintenance plan.

Using the success of PWSAC as a model, the Board of Fisheries has also directed the two Southeast regional aquaculture associations (NSRAA and SSRAA) to develop an allocation plan for hatchery stocks by March 1993. There is considerable debate among participants and observers as to whether this can be done. Unlike the Prince William Sound plan, which deals primarily with one species and a single user group, Southeast must address deep-seated conflicts between two aquaculture associations, three commercial user groups and several species of salmon, as well as factoring in the complexities of the U.S./Canada salmon treaty.

6. Management issues.

Another complaint is that regional comprehensive salmon plans often focus exclusively on production goals for a hatchery, but provide little specific information on fishery management. Statements such as "management agencies and fishermen should work together to find the best solutions currently available to reverse declines" are common.

Initially, hatchery permitting was a two-stage process. The preliminary application included identification of such things as site, species, and run-timing. It contained little detail, and was given a relatively cursory review by ADF&G to notify the permittee if there were any significant potential problems before the applicant went to the expense of a full permit application. In 1985, however, hatchery permits were placed under the Coastal Zone Management process. As part of permit reform, FRED planners were told that only a single application could be required.

To replace the preliminary application, FRED now requires an initial *Management Feasibility Analysis* (MFA) be completed before a final application is submitted. The MFA covers the basics of siting, species, timing, and magnitude of production, and is developed by the Commercial Fisheries and Sport Fisheries Divisions to avoid potential

management problems. Quite often, if red flags are raised during this review process, the original proposal ends up being modified.

Additionally, once an application is deemed acceptable by the department, the department's divisions are again given further opportunity to comment.

FRED planners believe that they have never permitted a hatchery or enhancement project that fisheries managers did not initially approve.

7. Uniform review.

State hatcheries and projects are not subject to the same permitting requirements as PNPs. Some fishermen believe that state projects cause the most allocation, management, and potential biological problems because of the lack of this additional layer of scrutiny. They would like to see permits required for state hatcheries and projects, as well as for PNP projects.

FRED Division believes adding this requirement is unnecessary. Although PNP-type permits are not required, state projects are reviewed through the Coastal Zone Management review process. In addition, the annual management plans for state facilities are submitted to the Regional Planning Teams for review. Some people believe these projects often receive more critical review than the PNP projects. Both state and PNP operations also require Fish Transport Permits (FTPs).

8. Criteria to show public benefit.

Four criteria must be considered by the RPT to determine if a permit application is in compliance with the regional comprehensive salmon plan:

- the contribution the proposed hatchery would make to the common property fishery;
- the provisions for protecting wild stocks from any adverse effects which may originate from the proposed hatchery;
- the compatibility of the proposed hatchery with the goals and objectives of the comprehensive salmon plan for the region; and
- whether the proposed hatchery would make the best use of the site's potential to benefit the common property fishery.

Critics say these criteria should be expanded to consider other public benefits and costs. Possible additions include marketability, a detailed cost-benefit analysis, and ongoing genetic and biological monitoring.

9. Operation performance reviews and permit revocation.

State managers and RPT gear group representatives are also concerned about ADF&G's authority over hatcheries that are out of compliance with state laws, regulations, and permit requirements.

Present regulations allow RPTs, at the direction of the ADF&G commissioner, to review a hatchery's compliance with statutes and regulations, and to recommend the suspension, alteration or revocation of a permit if certain performance standards are not met such as survival rates and contribution to the common property fishery. However, a recent attorney general's opinion required that one hatchery facing revocation of a permit must be given a hearing before an administrative officer under the Administrative Procedures Act. This can be a relatively lengthy process.

With the potential risk of impacts on the state's common property fisheries, managers and some RPT members believe a mechanism to allow for the timely revocation of a permit is necessary. They advocate for a change in the statute to allow the ADF&G commissioner to revoke, suspend or alter a permit for any violation of Title 16 without going through APA requirements.

10. Hatchery Siting Privileges

If a region has an organized aquaculture association, that association, under state statutes, has the preference rights to all potential hatchery sites in that region. Non-association PNPs (Mom and Pops) have expressed concern that giving priority use of potential sites to an association is not good public policy. The Mom and Pop operations believe that any unused hatchery sites should be available to both associations and non-association PNPs.

11. Canadian evaluation model

The Canadian government is considered to have a model evaluation program of its national salmon enhancement program. Under the auspices of the Internal Audit and Program Evaluation Branch of the Department of Fisheries and Oceans, this program is intended to provide a thorough and comprehensive review of the program, by facility.

The first evaluation project began in 1985 and concluded that there was not enough production and biological data available to carry out a proper program evaluation. The program audit branch then designed the optimum evaluation framework and determined what kind of data would be needed. These data included biological and production information, as well as an analysis of economic costs and benefits. With that data in hand, program auditors are now preparing to spend a year reviewing the entire program, with a final report due in March 1993. Federal funds are being used for this project, although university staff and consulting firms are conducting the actual evaluation.

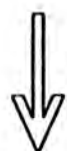
OPTIONS FOR POSSIBLE CONSIDERATION:

- Working with the public and user groups to develop statewide goals and objectives for the state's entire fisheries enhancement program.
- Directing FRED Division to develop a program to implement these goals and objectives.
- Declaring a moratorium on further hatchery development or increased production until the Legislature's economic cost-benefit studies are complete and a full assessment of the state's program can be made.

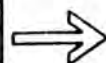
- Development of a statewide planning process.
- Development of a statewide production plan.
- Requiring FRED to develop a comprehensive annual report that not only compiles production figures from state and PNP facilities, projects, and current management regimes, but also includes future production and management plans.
- Evaluation of the composition and procedures of the RPT to determine if changes in the RPT structure are necessary.
- Expansion of state statutes to require all hatcheries, including state facilities, to comply with a single planning and permitting process, with the same requirements for monitoring and review.
- Widening the scope of RPT review, including recommendations for allocation of enhancement production.
- Providing adequate funding for planning.
- Reviewing the required Management Feasibility Analysis to determine if it needs to be a more comprehensive review.
- As part of permit review and solicitation of state loans, consideration of adding new criteria to show public benefit, including marketability, a detailed cost/benefit analysis instead of a financial feasibility analysis, a more specific indication of the "significant contribution" to be made to the common property fishery, and some kind of environmental assessment.
- Providing concrete direction for the timely performance review of PNP hatcheries and a more workable mechanism for closing or converting hatcheries not making a "significant" contribution to the common property fishery.
- Exempting the alteration, suspension or revocation of an enhancement permit for violations from the Administrative Procedures Act.
- Instituting a regular review process similar to the Canadian model.
- Clarifying Board of Fisheries authority to regulate hatchery production levels.
- Re-evaluation of the policy of giving regional aquaculture associations the preference rights to develop future hatchery sites in the region.

Planning Process

Regional Planning Team



Historic harvests,
production/harvest
goals by area, species



Regional Comprehensive Plans

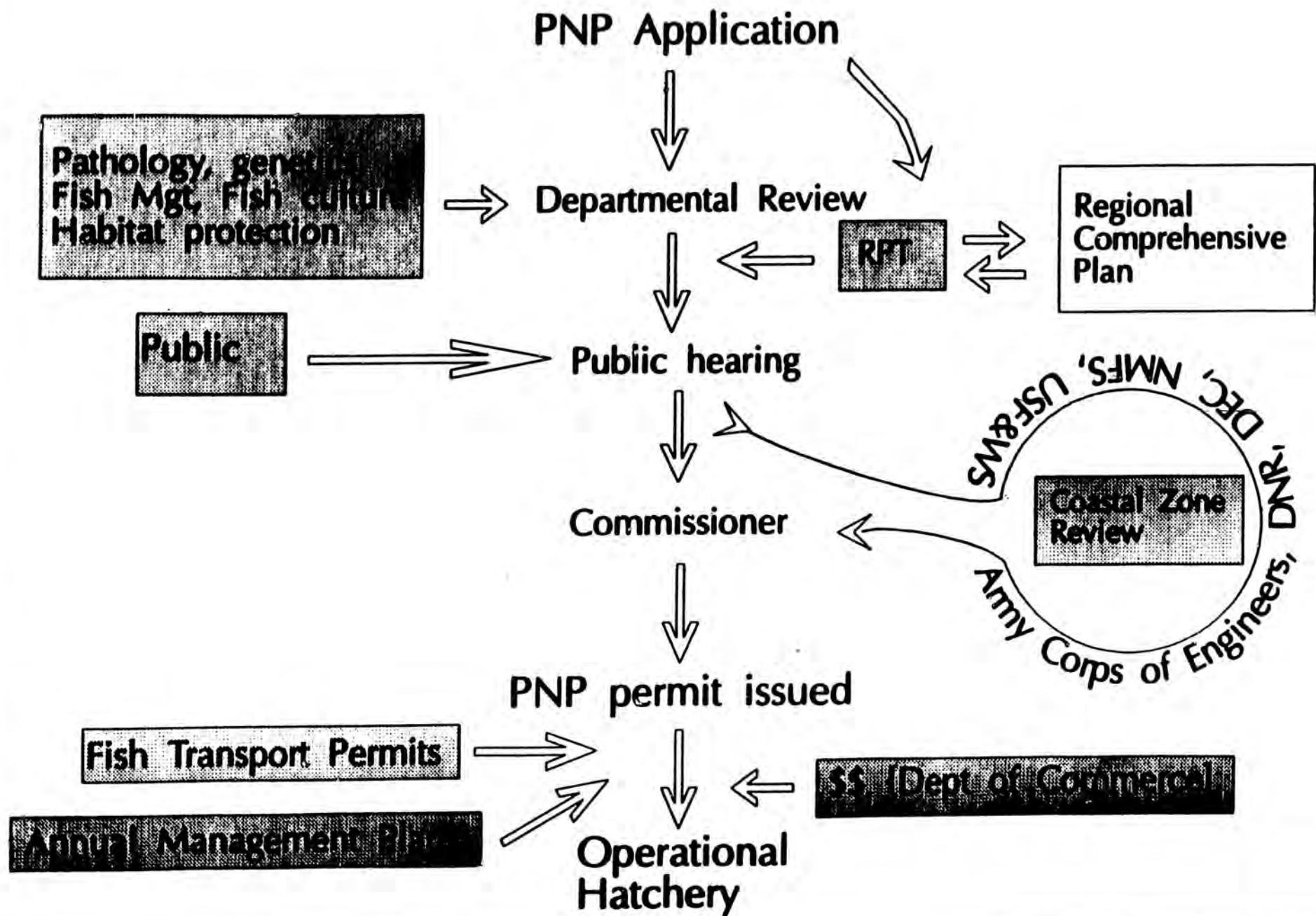


Project
opportunities
to fill gaps

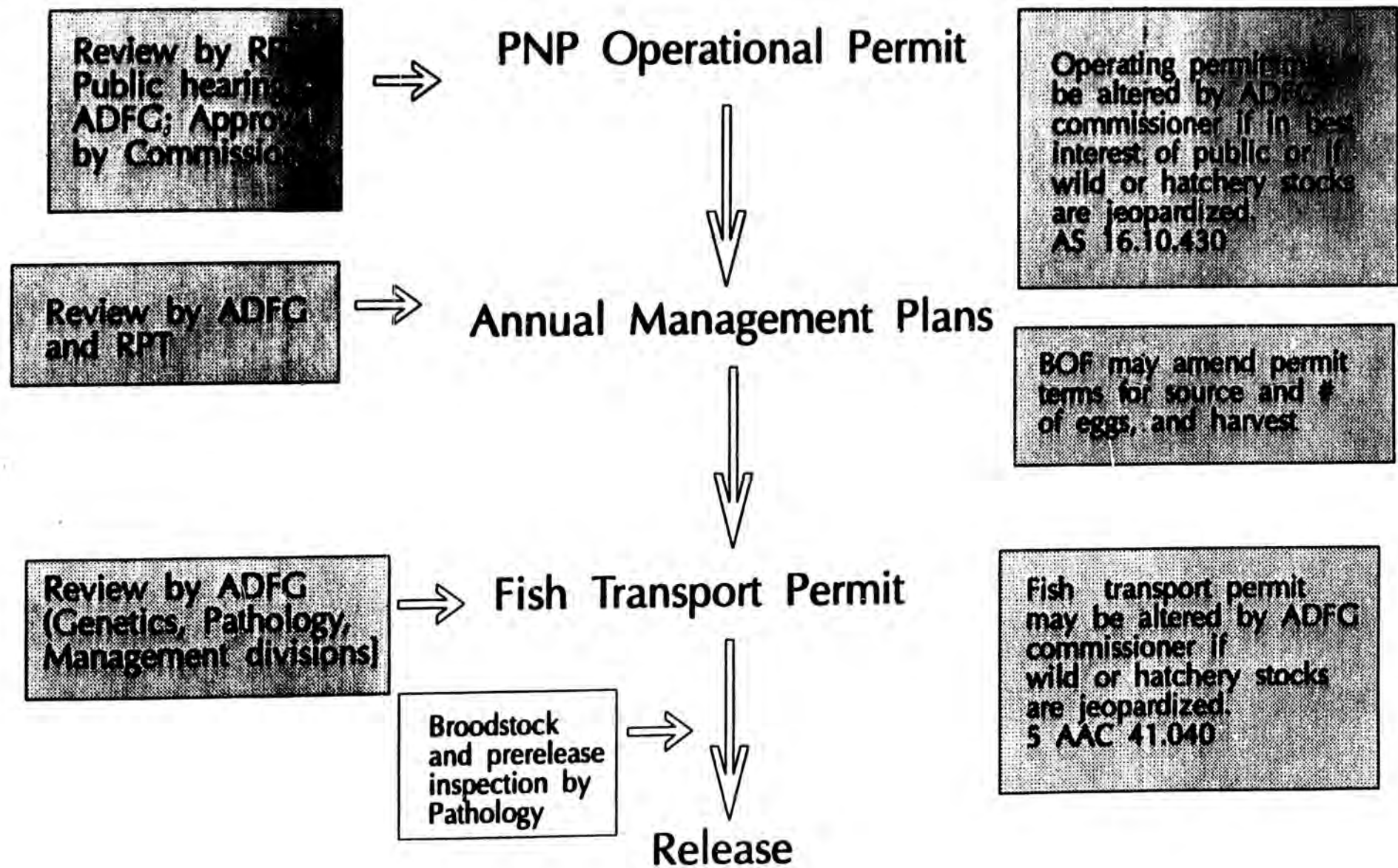


Attachment to
Chapter VI.

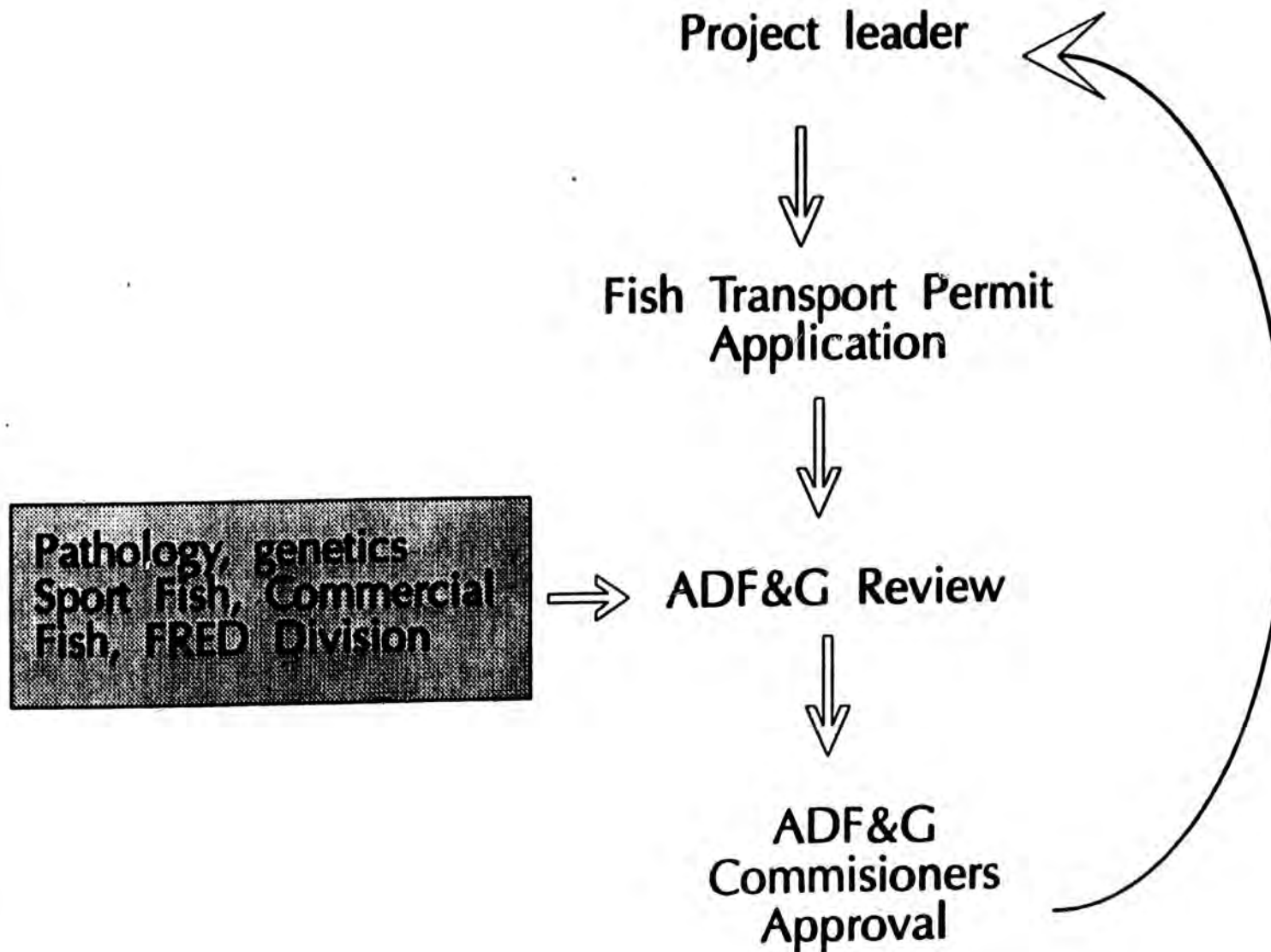
PNP Application Process



Regulation of PNP Hatcheries



Fish Transport Permit Process



Sec. 16.10.342. Special account established. (a) There is established as a special account within the commercial fishing revolving loan fund the foreclosure expense account.

(b) *[Repealed, § 72 ch 113 SLA 1982.]*

(c) The commissioner may expend money credited to the foreclosure expense account when necessary to protect the state's security interest in collateral on loans granted under AS 16.10.300 — 16.10.370 or to defray expenses incurred during foreclosure proceedings after a default by an obligor. (§ 4 ch 83 SLA 1978; am § 72 ch 113 SLA 1982)

Sec. 16.10.350. Administration of fund. The commissioner shall administer the loan fund. (§ 1 ch 134 SLA 1972)

Sec. 16.10.355. Disposal of property acquired by default or foreclosure. The department shall dispose of property acquired through default or foreclosure of a loan made under AS 16.10.300 — 16.10.370 or former AS 16.10.650 — 16.10.720. Disposal shall be made in a manner that serves the best interests of the state, and may include the amortization of payments over a period of years, but may not be by lease. (§ 11 ch 79 SLA 1985)

Sec. 16.10.360. Definitions. In AS 16.10.300 — 16.10.370

(1) "commission" means the Alaska Commercial Fisheries Entry Commission;

(2) "commissioner" means the commissioner of commerce and economic development;

(3) "debtor" means an individual commercial fisherman who either initially contracts for a loan under AS 16.10.333 — 16.10.337 or assumes a loan as provided in those sections;

(4) "department" means the Department of Commerce and Economic Development. (§ 1 ch 134 SLA 1972; am § 5 ch 83 SLA 1978)

Revisor's notes. — Reorganized in 1983 to alphabetize the defined terms. **Cross references.** — For further definitions, see AS 16.05.940.

Sec. 16.10.370. Short title. AS 16.10.300 — 16.10.370 may be cited as the Commercial Fishing Loan Act. (§ 1 ch 134 SLA 1972)

Article 8. Salmon Hatcheries.

Section	Section
375. Regional salmon plan	443. Department assistance and cooperation
380. Regional associations	
400. Permits for salmon hatcheries	445. Egg sources
410. Hearings before permit issuance	450. Sale of salmon and salmon eggs by hatchery
420. Conditions of a permit	460. Inspection of hatchery
430. Alteration, suspension or revocation of permit	470. Annual report
440. Regulation	

Cross references. — For legislative findings and purpose of AS 16.10.375 — 16.10.620, see 1, ch. 59 SLA 1979, in the 1979 Temporary and Special Acts and Resolves.

Sec. 16.10.375. Regional salmon plan. The commissioner shall designate regions of the state for the purpose of salmon production and have developed and amend as necessary a comprehensive salmon plan for each region, including provisions for both public and private nonprofit hatchery systems. Subject to plan approval by the commissioner, comprehensive salmon plans shall be developed by regional planning teams consisting of department personnel and representatives of the appropriate qualified regional associations formed under AS 16.10.380. (§ 2 ch 161 SLA 1976; am § 2 ch 154 SLA 1977)

Sec. 16.10.380. Regional associations. (a) The commissioner shall assist in and encourage the formation of qualified regional associations for the purpose of enhancing salmon production. A regional association is qualified if the commissioner determines that

(1) it is comprised of associations representative of commercial fishermen in the region;

(2) it includes representatives of other user groups interested in fisheries within the region who wish to belong; and

(3) it possesses a board of directors which includes no less than one representative of each user group that belongs to the association.

(b) In this section "user group" includes, but is not limited to, sport fishermen, processors, commercial fishermen, subsistence fishermen, and representatives of local communities.

(c) A qualified regional association, when it becomes a nonprofit corporation under AS 10.20, is established as a service area in the unorganized borough under AS 29.03.020 for the purpose of providing salmon enhancement services. (§ 2 ch 161 SLA 1976; am § 2 ch 59 SLA 1979)

NOTES TO DECISIONS

Cited in State, N.S.E. Regional Aquaculture Ass'n v. Alex, Sup. Ct. Op. No. 2488 (File Nos. 5065, 5086, 5142), 646 P.2d 203 (1982).

Sec. 16.10.400. Permits for salmon hatcheries. (a) The commissioner or a designee may issue a permit, subject to the restrictions imposed by statute or regulation under AS 16.10.400 — 16.10.470, to a nonprofit corporation organized under AS 10.20, after the permit application has been reviewed by the regional planning team, for the construction and operation of a salmon hatchery.

(b) The application for a permit under this section shall be on a form prescribed by the department and be accompanied by an application fee of \$100.

(c) A hatchery permit is nontransferable. If a permit holder sells or leases a hatchery for which a permit is issued under this section, the new operator shall apply for a new permit under this section.

(d) *[Repealed, § 19 ch 154 SLA 1977.]*

(e) A qualified regional association formed under AS 16.10.380, if it has become a nonprofit corporation under AS 10.20, has a preference right to a permit if its proposed hatchery is provided for in the comprehensive plan for that region developed under AS 16.10.375 and the fresh water source exceeds one cubic foot per second minimum flow. Any other local nonprofit hatchery corporation approved by a qualified regional association has an identical preference right.

(f) Except for permits issued before June 16, 1976, a permit may not be issued for construction or operation of a hatchery on an anadromous fish stream unless the stream has been classified as suitable for enhancement purposes by the commissioner. The commissioner shall undertake to make such classifications in conjunction with the development of the comprehensive plan under AS 16.10.375.

(g) During the development of a comprehensive plan for a region no permit may be issued for a hatchery unless the commissioner determines that such an action would result in substantial public benefits and would not jeopardize natural stocks. (§ 2 ch 111 SLA 1974; am § 3 ch 161 SLA 1976; am §§ 3, 19 ch 154 SLA 1977)

Cross references. — For legislative intent in connection with the enactment of AS 16.10.400 — 16.10.470, see § 1, ch. 111, SLA 1974, in the Temporary and Special Acts.

Sec. 16.10.410. Hearings before permit issuance. (a) At least 30 days before the issuance of a permit under AS 16.10.400, a public hearing shall be held in a central location in the vicinity of the proposed hatchery facility.

(b) Notice of the hearing shall be published in a newspaper of general circulation once a week for three consecutive weeks, with completion of the notice at least 10 days before the hearing.

(c) The hearing shall be conducted by the department, with a presentation by the permit applicant of a plan for the proposed hatchery, describing its capacity and any other relevant facts which may be of interest to the department or the public. Interested members of the public shall be afforded an opportunity to be heard.

(d) The department shall record and consider objections and recommendations offered by the public at the hearing conducted under this section. It shall respond in writing, within 10 days after the hearing is held, to any specific objections offered by a member of the public at the hearing. (§ 2 ch 111 SLA 1974)

Sec. 16.10.420. Conditions of a permit. The department shall require, in a permit issued to a hatchery operator, that

(1) salmon eggs procured by the hatchery must be from the department or a source approved by the department;

(2) no salmon eggs or resulting fry be placed in waters of the state other than those specifically designated in the permit;

(3) no salmon eggs or resulting fry, sold to a permit holder by the state or by another party approved by the department, may be resold or otherwise transferred to another person;

(4) no salmon be released by the hatchery before department approval, and, for purposes of pathological examination and approval, the department shall be notified of the proposed release of salmon at least 15 days before the date of their proposed release by the hatchery;

(5) diseased salmon be destroyed in a specific manner and place designated by the department;

(6) adult salmon be harvested by hatchery operators only at specific locations as designated by the department;

(7) surplus eggs from salmon returning to the hatchery be made available for sale first to the department and then, after inspection and approval by the department, to operators of other hatcheries authorized by permit to operate under AS 16.10.400 — 16.10.470;

(8) if surplus salmon eggs are sold by a permit holder to another permit holder, a copy of the sales transaction be provided to the department;

(9) *[Repealed, § 5 ch 110 SLA 1980.]*

(10) a hatchery be located in an area where a reasonable segregation from natural stocks occurs, but, when feasible, in an area where returning hatchery fish will pass through traditional salmon fisheries. (§ 2 ch 111 SLA 1974; am § 5 ch 110 SLA 1980)

Sec. 16.10.430. Alteration, suspension or revocation of permit. (a) If a permit holder fails to comply with the conditions and terms of the permit issued under AS 16.10.400 — 16.10.470 within a reasonable period after notification of noncompliance by the department, the permit may be suspended or revoked, in the discretion of the commissioner after the regional planning team for the area in which the hatchery is located is notified and granted an opportunity to comment upon the proposed suspension or revocation.

(b) If the commissioner finds that the operation of the hatchery is not in the best interests of the public, the commissioner may alter the conditions of the permit to mitigate the adverse effects of the operation, or, if the adverse effects are irreversible and cannot be mitigated sufficiently, initiate a termination of the operation under the permit over a reasonable period of time under the circumstances, not to exceed four years. During the period of time that the operation is being terminated, the permit holder may harvest salmon under the terms of

the permit but may not release additional fish. (§ 2 ch 111 SLA 1974; am § 4 ch 154 SLA 1977)

Sec. 16.10.440. Regulation. (a) Fish released into the natural waters of the state by a hatchery operated under AS 16.10.400 — 16.10.470 are available to the people for common use and are subject to regulation under applicable law in the same way as fish occurring in their natural state until they return to the specific location designated by the department for harvest by the hatchery operator.

(b) The Board of Fisheries may, after the issuance of a permit by the commissioner, amend by regulation adopted in accordance with the Administrative Procedure Act (AS 44.62), the terms of the permit relating to the source and number of salmon eggs, the harvest of fish by hatchery operators, and the specific locations designated by the department for harvest. The Board of Fisheries may not adopt any regulations or take any action regarding the issuance or denial of any permits required in AS 16.10.400 — 16.10.470. (§ 2 ch 111 SLA 1974; am § 24 ch 206 SLA 1975; am § 3 ch 59 SLA 1979)

Sec. 16.10.443. Department assistance and cooperation.

(a) Before and after permit issuance under AS 16.10.440 — 16.10.470, the department shall make every effort, within the limits of time and resources, to advise and assist applicants or permit holders, as appropriate, in the planning, construction, or operation of salmon hatcheries.

(b) Nothing in this section exempts an applicant or permit holder from compliance with AS 16.10.400 — 16.10.470 or from compliance with the regulations or restrictions adopted under AS 16.10.400 — 16.10.470. (§ 1 ch 97 SLA 1975)

Sec. 16.10.445. Egg sources. (a) The department shall approve the source and number of salmon eggs taken under AS 16.10.400 — 16.10.470.

(b) Where feasible, salmon eggs utilized by a hatchery operator shall first be taken from stocks native to the area in which the hatchery is located, and then, upon department approval, from other areas, as necessary. (§ 2 ch 111 SLA 1974)

Sec. 16.10.450. Sale of salmon and salmon eggs by hatchery. A hatchery operator who sells salmon returning from the natural waters of the state, or sells salmon eggs to another hatchery operating under AS 16.10.400 — 16.10.470, after utilizing the funds for reasonable operating costs, including debt retirement, expanding its facilities, salmon rehabilitation projects, fisheries research, or for costs of operating the qualified regional association for the area in which the hatchery is located, shall expend the remaining funds on other fisher-

ies activities of the qualified regional association. Fish returning to hatcheries and sold for human consumption shall be of comparable quality to fish harvested by commercial fisheries in the area, and shall be sold at prices commensurate with the current market. (§ 2 ch 111 SLA 1974; am § 5 ch 154 SLA 1977)

Sec. 16.10.460. Inspection of hatchery. (a) As a condition of and in consideration for a permit to operate a hatchery under AS 16.10.400 — 16.10.470, an inspection of the hatchery facility by department inspectors shall be permitted by the permit holder at any time the hatchery is operating. The inspection shall be conducted in a reasonable manner.

(b) The cost of an inspection performed by the department under AS 16.10.400 — 16.10.470 shall be borne by the department. (§ 2 ch 111 SLA 1974; am § 4 ch 110 SLA 1980)

Sec. 16.10.470. Annual report. (a) A person who holds a permit for the operation of a salmon hatchery under AS 16.10.400 — 16.10.470 shall submit an annual report no later than December 15 to the department and to the qualified regional association for the area in which the hatchery is located, to include but not be limited to information pertaining to species; brood stock source; number, age, weight, and length of spawners; number of eggs taken and fry fingerling produced; and the number, age, weight, and length of adult returns attributable to hatchery releases, on a form to be provided by the department.

(b) A person who holds a permit for the operation of a salmon hatchery under AS 16.10.400 — 16.10.470 and each regional association levying a voluntary assessment under AS 16.10.540 shall submit an annual financial report to the Department of Commerce and Economic Development on a form to be provided by the Department of Commerce and Economic Development. (§ 2 ch 111 SLA 1974; am § 6 ch 154 SLA 1977; am § 4 ch 59 SLA 1979; am § 31 ch 14 SLA 1987)

Effect of amendments. — The 1987 amendment substituted "voluntary assessment under AS 16.10.540" for "royalty assessment under AS 16.10.530" in subsection (b).

Sec. 16.10.475. Definitions. [Repealed, § 32 ch 14 SLA 1987.]

Article 9. Fisheries Enhancement Loan Program.

Section	Section
500. Declaration of policy	510. Powers and duties of the commissioner
505. Fisheries enhancement revolving loan fund	520. Limitation on loans
507. Special account established	525. Repayment of principal and interest on loans

SCOMM

74:29

CHAPTER VII. BIOLOGICAL/GENETIC ISSUES

In November 1991, in Cordova, Alaska, the Prince William Sound Science Center (PWSSC) and the School of Fisheries and Ocean Sciences, University of Alaska Fairbanks, convened a group of world-renowned experts to examine "The Biological Basis for Maintaining Strong Co-existing Stocks of Natural and Enhanced Salmon Populations in Alaska." This workshop followed a series of international symposiums on this topic during the past two years. Top fisheries biologists, ecologists and geneticists from the United States, Norway, Sweden, the Soviet Union and Japan were present at the Cordova workshop. As a follow-up to the workshop, the group intends to produce a summary report and list of recommended policies and procedures to be considered by the state of Alaska in managing its wild and enhanced salmon stocks. That report is expected in late February.

The cumulative effect of hydroelectric dams, habitat destruction, overfishing, and large-scale hatcheries has led to the decimation of many wild salmon stocks in Pacific Northwest states. Biologists in states with a long history of hatchery programs are generally less enthusiastic about these programs than biologists in areas such as Alaska and British Columbia with comparatively recent programs. *Although poor hatchery practices can clearly endanger wild salmon populations, scientists do not agree on the extent to which hatcheries with sound practices can co-exist with sustained healthy runs of wild salmon.*

The lack of consensus among scientists largely results from insufficient data and research, and at times, professional bias. Even where information exists, however, it is often subject to conflicting interpretations. To complicate matters, results of specific studies may not be transferable to other areas or salmon species, and year-to-year environmental changes may affect the results of these studies.

THE GENETIC EFFECTS OF HATCHERIES

Most scientists agree that it is essential to have healthy wild stocks to maintain the health and genetic diversity of both wild and hatchery stocks; genetic diversity must be preserved. Scientific knowledge about the genetic impact on wild stocks of hatchery fish, however, is still incomplete. Reduction in the fitness of salmon stocks, to the extent it has been documented, may involve numerous factors. Most scientists agree that hatcheries can complicate mixed-stock fisheries and affect the genetic composition of wild fish stocks. Scientists do not agree on the extent to which genetic changes affect the short- or long-run fitness of wild stocks.

Straying and intermingling of stocks is a major concern to scientists. The extent of straying, the variables involved in imprinting, and the effects of interbreeding are largely unknown. Large-scale ocean ranching appears to set the stage for straying of wild stocks in the harvest areas of enhanced stocks and also for hatchery fish to stray into the natural streams. What impact this has on the genetic diversity of salmon stocks in a given region is a question that remains to be answered. However, the concern is that intermingling may reduce the fitness of the locally adapted populations.

It is known that the greater the distance between the donor stream or hatchery and the release site, the greater the amount of straying. Many scientists are concerned about the extensive releases at remote sites practiced by many hatchery operations today, with many more planned for the future. They fear that such

straying could potentially, in time, destroy genetic diversity -- resulting in a permanent, irreversible loss. Some scientists believe remote releases should be banned altogether. Others believe they should be permitted with stringent controls and careful monitoring.

OCEAN CARRYING CAPACITY

Some scientists suspect that the carrying capacity of nearshore marine waters and the high seas for salmon may be exceeded by large-scale releases of hatchery salmon. A reduction in the average size of salmon was reported throughout the Pacific region in 1991, but various factors may be responsible. Since 95 percent of the growth of salmon occurs at sea, some researchers believe ocean conditions affect the size of salmon more than competition. Much evidence, however, supports the theory of density-dependent growth for some salmon species, although there is considerable debate regarding its occurrence. More information is needed on the effects of predation and competitors.

DISEASE

Few studies document the transmittal of diseases between hatchery and wild salmon, and there is no documentation of such transmittal in Alaska. Where transmittal of a disease by hatchery salmon has been documented, it occurred after fish were transplanted long distances. Hatchery fish appear to be more vulnerable to disease than wild fish because of the stress of hatchery conditions and large concentrations of eggs and fry. Norway has had considerable problems with disease transmitted by farmed salmon that have escaped and mixed with wild stocks.

Active fish pathology laboratories are maintained by the FRED Division in both Juneau and Anchorage. Their basic function is to implement policies and procedures that guard against the spread of fish and shellfish diseases in Alaska. Reviewing fish transport permits in order to reduce the occurrence of disease is a major task of the labs, as is examining each broodstock for disease prior to its use in a hatchery.

STATE GENETICS PROGRAM AND POLICY

The state genetics program is intended to implement policies and procedures that protect and maintain the genetic uniqueness of Alaska's wild salmon stocks in the face of North America's largest salmon enhancement program. The state's fish genetics policy, considered to be one of the most stringent in the world, was last revised in 1985, and will be reexamined and updated this year.

Alaska's genetic policy contains guidelines and restrictions intended to protect the genetic integrity of wild stocks. The *goal* is to maintain adequate genetic variability, ensuring that the enhanced stock will be able to adapt to changing environmental conditions.

Geneticists have two primary concerns in protecting wild stocks and implementing a successful enhancement program. The first is possible genetic impacts due to gene flow between wild or enhanced stocks; the primary concern being, of course, for wild stocks. The second concern is the loss of genetic variation within or among stocks. Both impacts

can potentially cause the reduction of total fitness in wild stocks and hatchery broodstocks. These problems are addressed in the policy's three main topic areas: stock transport, protection of wild stocks, and the maintenance of genetic variation.

Since specific knowledge of salmon population genetics and the genetic impacts of salmon enhancement on wild stocks was limited, the 1985 genetic policy was based primarily on information from agricultural genetics and research on other species. As a result, the policy contains guidelines that are rather flexible. The policy suggests that because scientific knowledge is limited, fish transport should be evaluated conservatively. For example, if genetic similarity decreases with distance, arbitrary limits must be set on the distance a stock can be transported. For that reason, the Fish Transport Permit process is the prime regulatory tool in the genetic policy. *ADF&G is attempting to clarify some of the flexible guidelines in the revised policy by incorporating knowledge gained from recent studies of the population genetics of salmonids.*

The genetic policy also acknowledges that all salmon runs are not of equal importance. The effect of a salmon enhancement project depends to some degree on the relative value of the stock that might be impacted. However, the policy says that the concept of "significant stock" only relates to the size of a fish population in the context of local importance and use. A population that would be considered insignificant in size in one region, may be of vital importance in another region.

OPTIONS FOR POSSIBLE CONSIDERATION:

Although a report of recommended management actions resulting from the Cordova workshop is expected in late February, some preliminary options for consideration include:

- Evaluation of how well the current hatchery program protects wild salmon from possible negative effects of hatchery salmon. Such a review would help policy makers determine the risk of various alternatives for the future of Alaska hatchery program.
- Increasing the amount of genetic monitoring required of hatcheries by directing ADF&G to continuously review and analyze resulting data.
- Obtaining consensus about research priorities concerning the interaction between hatchery and wild fish in Alaska, coordinating future studies, and deciding how to apply the results of those studies to current management practices.
- Conducting research to define the minimum conditions for imprinting for remote release programs.
- Review of current and future programs for their compliance with the state genetics policy.
- Placing greater emphasis on management concerns in the permitting process in order to protect wild stocks.
- Re-examination of escapement goals in order to maximize wild productivity.

DRAFT ** DRAFT ** DRAFT ** DRAFT ** DRAFT

- Increased use of marking and tagging programs to monitor interactions between hatchery and wild populations.
- Policy development to minimize inbreeding and straying, including an evaluation of remote releases.
- Treating a remote release site as a de facto hatchery site in terms of broodstock and hatchery site guidelines, even if all fish are expected to be harvested.
- Identification of genetic population structures to determine what populations are genetically distinct.
- Survey of populations prior to any enhancement activity to provide a baseline for subsequent genetic monitoring. Evaluation of genetic consequences of hatchery production on adjacent populations during phased-in expansion, with production increases halted if adverse impacts are noted.
- Monitoring wild and hatchery stocks to determine extent of straying and intermingling.

Planning Process

Regional Planning Team



Historic harvests,
production/harvest
goals by area, species



Regional Comprehensive Plans

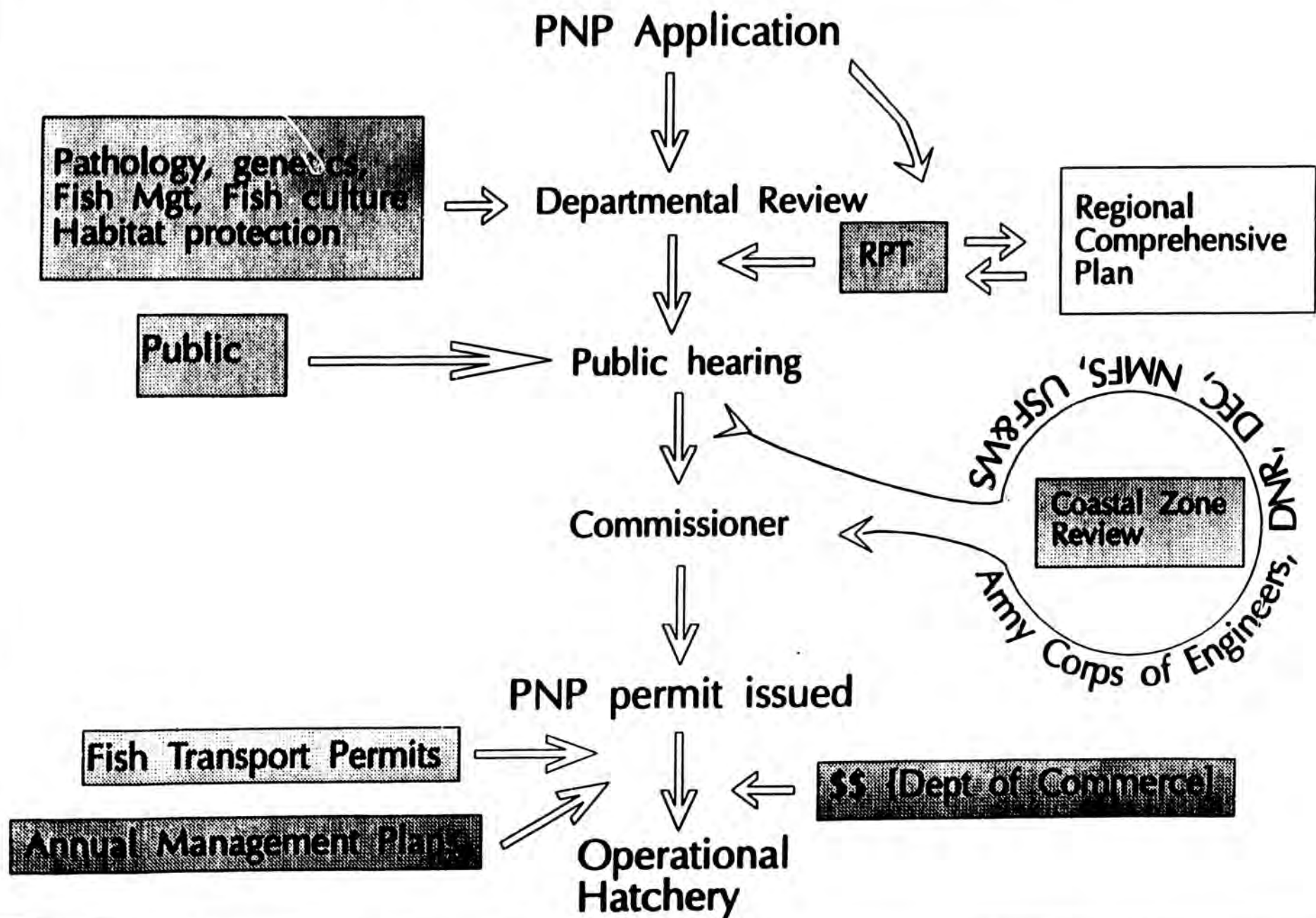


Project
opportunities
to fill gaps

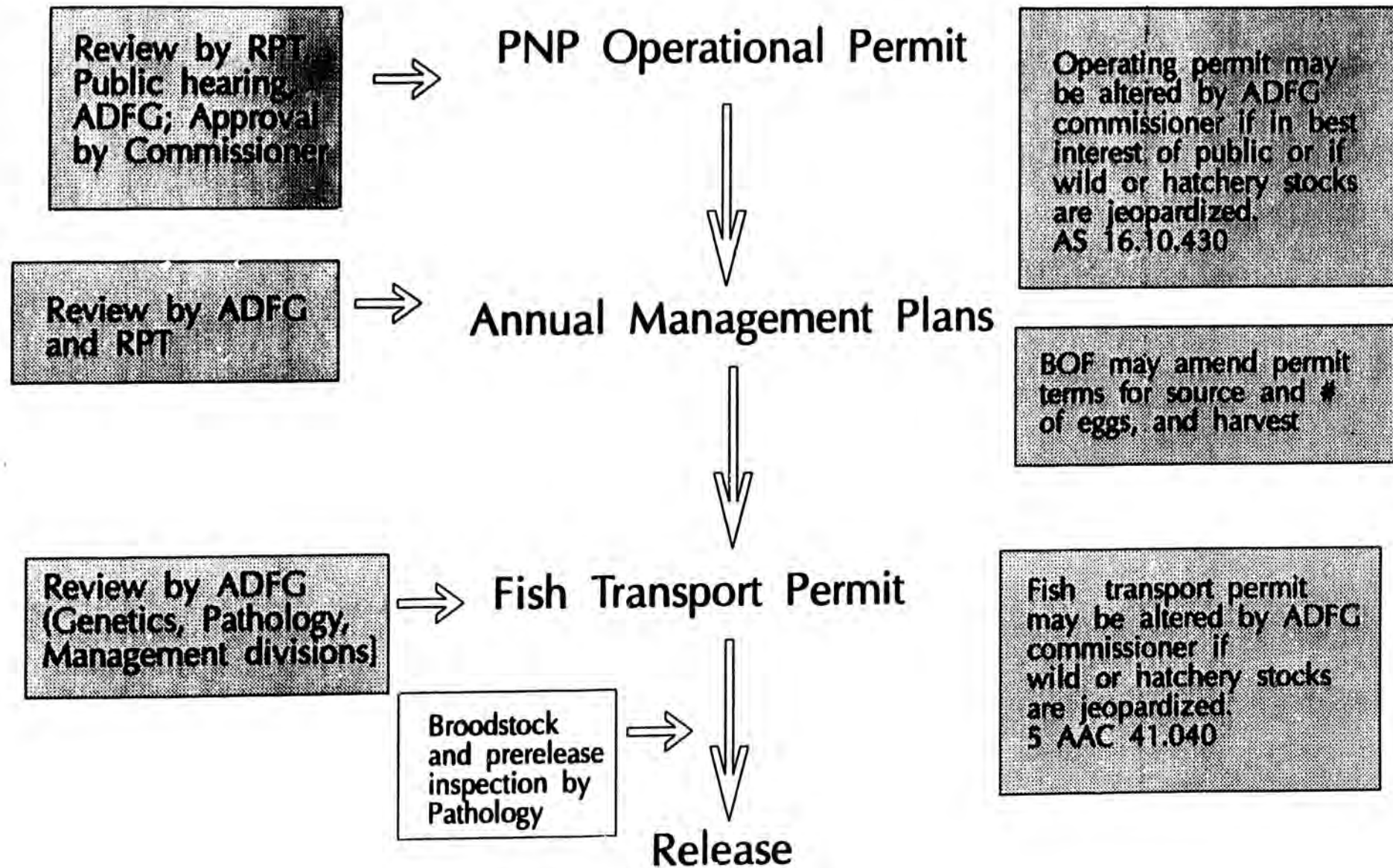


Attachment to
Chapter VI.

PNP Application Process



Regulation of PNP Hatcheries



Alaska State Legislature

Legislative Research Agency



P.O. Box Y
Juneau, AK 99811-3100
Phone: (907) 165-3991
Fax: (907) 163-3331

September 11, 1991

MEMORANDUM

TO: Senator Lloyd Jones
FROM: Glenn T. Gray^{GTG}
Legislative Analyst
RE: Effect of Hatchery Salmon on Wild Salmon
Research Request 91.303

You requested information about how hatchery-produced salmon affect wild stocks. You asked us to address five specific questions relating to this issue:

- 1) Do hatchery-produced fish cause genetic dilution of natural stocks?
- 2) Does the harvest of hatchery salmon result in unintended harvest of wild stocks?
- 3) Do hatchery salmon compete with wild stocks for food?
- 4) Is predation by hatchery salmon on wild salmon a significant threat to wild stocks?
- 5) Are wild stocks vulnerable to diseases that originate with hatchery-produced fish?

For this memorandum we reviewed studies by scientists from Alaska, other states, Canada, Japan, the Soviet Far East and Europe. We also reviewed abstracts of papers presented at recent conferences concerning the genetic implications of interaction between enhanced and wild fish. We then discussed these studies and related topics with several scientists and personnel from the Alaska Department of Fish and Game (ADF&G).

This memorandum begins by defining some important terms which are commonly used in discussions of salmon biology. Next, an introduction provides an overview of current knowledge of the effects of hatchery salmon on wild fish. Then each of the five questions you posed are addressed. We also identify other possible biological effects of hatchery salmon on wild stocks. This is followed by a discussion of how management can minimize possible negative effects of hatcheries. The memorandum ends with a summary of concerns voiced by biologists about hatcheries and research needs for the future.

DEFINITIONS

Biologists have traditionally recognized six species of Pacific salmon: coho (*Oncorhynchus kisutch*), chum (*Oncorhynchus keta*), chinook (*Oncorhynchus tshawytscha*), pink (*Oncorhynchus gorbuscha*), sockeye (*Oncorhynchus nerka*), and masu (*Oncorhynchus masu*). All but masu salmon may be found in Alaska waters. Recently, cutthroat trout (*Oncorhynchus clarki*) and steelhead (*Oncorhynchus mykiss*) have been reclassified as Pacific salmon. Atlantic salmon (*Salmo salar*) are not native to the Pacific, but some of them have escaped from fish farms in British Columbia.¹ Salmonids are a biological grouping which includes salmon species as well as related fish such as trout, char and whitefish. Most salmon are anadromous, that is they have both freshwater and saltwater residencies during different periods of their life. Some Pacific salmon spend their whole life in fresh water: Kokanee salmon are sockeye salmon that remain in lakes, rainbow trout are steelhead that live in lakes or streams, and cutthroat trout may also spend their life in fresh water.

We use the term stock to refer to groups of fish of the same species with a similar genetic background that return to spawn in the same locality, and do not generally interbreed with other groups of fish.² Some watersheds may have two or more salmon stocks, but these stocks usually spawn at different times or at different parts of the watershed.³ Fish of a particular stock have a unique genetic make-up because wild salmon generally do not interbreed with other stocks. (As a result of natural straying, stocks spawning near each other would be expected to have more similar traits than stocks located further apart.) Some fishery experts prefer the term population because the term stock is often used in many different contexts. Alaska statutes, for example, define fish stocks less precisely.⁴

A wild stock, as used in this memorandum, is a distinct group of fish descended from a population of fish historically found in a particular area that have not bred to a significant degree with fish from another area.⁵ A natural run is a self-sustaining group of "wild" fish in a natural environment that may or may not have genetic influence from hatchery or farmed fish.

¹Although Atlantic salmon have been caught in Alaska waters, there have been no reports of naturally reproducing populations.

²The term stock generally refers to wild fish because hatchery fish may have originated from several different stocks.

³Larkin (1981) notes that in some instances the "differences among the tributaries of a single river are greater than those among comparable tributaries of different rivers" p. 1460.

⁴Alaska Statute 16.05.940(15) defines a fish stock as "a species, subspecies, geographic grouping or other category of fish manageable as a unit."

⁵The Oregon Wild Fish Management Policy defines a wild fish as one that is descended from a population present in the same area since 1800.

A mixed stock fishery occurs when fish of different wild stocks or hatchery and wild stocks intermingle during commercial harvest. Many of the fisheries in Alaska are mixed stock fisheries. Fisheries that occur after stocks separate are known as terminal fisheries. In watersheds where several stocks spawn, individual stocks may not completely separate until they reach up-water spawning grounds. While terminal fisheries are desirable from a management perspective because stocks may be harvested selectively, they may not be economically desirable because the quality of the flesh deteriorates as the fish approach fresh water.

Genetic variability is measured by the "number, frequency, and diversity of alleles present. Alleles are the variant forms of the gene" (Kelly et al. 1989, p. 60). A procedure known as protein electrophoresis measures allele frequencies and can be used to identify different stocks as well as genetic changes these fish may experience.⁶ Electrophoresis may also be used to measure heterozygosity (an indication of the variation of genes) to determine whether hatchery fish have lost genetic variability. Although electrophoresis is useful to determine a difference between some salmon stocks, the test does not reveal differences between all salmon stocks. Salmon stocks that cannot be differentiated by electrophoresis may be marked through a process known as genetic tagging.

Fisheries enhancement includes a variety of methods to augment natural runs. Hatcheries, construction of spawning channels, and lake fertilization are several examples of enhancement. Hatchery-produced fish are released to open water and are known as ranched fish; while fish raised in net pens and never released are known as farmed fish.

Fitness is the ability of fish to survive competition, predation and disease and return to native spawning streams. Some scientists suspect that wild fish are more fit than hatchery fish because wild fish have evolved through thousands of years of natural selection.

Brood stock are the fish used to start or maintain a hatchery. After salmon eggs hatch and their yolk sacs are consumed, the young fish are known as fry. When immature salmon migrate to the sea they are called smolts.

INTRODUCTION

Hatcheries have become a major contributor to commercial fisheries in the Pacific during the past two decades. As the numbers of wild salmon have decreased, Pacific Northwest states have become increasingly dependent on salmon produced by hatcheries. Except for masu and kokanee salmon, Japan depends almost entirely on hatchery stocks to supply its commercial fisheries

⁶Electrophoresis works better with chinook and chum salmon than with sockeye, pink, or coho salmon (Seeb, personal communication).

(Kelly et al. 1989).⁷ Although the Soviet Far East and Alaska still have many wild stocks, both have ambitious hatchery programs. For example, in recent years hatchery fish have comprised up to 98 percent of the total pink salmon harvest in Prince William Sound (Geiger et al. 1991). Despite the increasing contribution of salmon hatcheries, much is still unknown about the effect hatchery fish have on wild stocks. Additionally, some fear that the long-term productivity of hatcheries cannot be sustained (Hilborn 1990).

Each of the questions addressed in this memorandum are discussed separately, but they may actually be related, and addressing them separately may overlook cumulative impacts. For example, the genetic impact of straying salmon may be greater for a stock that has been reduced by over-fishing than for a healthy stock. Likewise, other influences of hatchery fish may have a detrimental cumulative effect when combined with practices destructive to wild fish (e.g., over-fishing and habitat destruction).

Most of the issues addressed in this memorandum ultimately relate to a concern about a reduction of genetic variability in wild salmon stocks. Genetic variability of a specific stock may be reduced when the size of that stock is significantly diminished. The numbers of a specific stock may be reduced by habitat loss, over-fishing, predation, disease, competition, and possibly by disturbance of wild fish nests (redds) by later-spawning salmon. Some geneticists believe that genetic integrity of a stock could also be at risk because of "genetic pollution" which occurs when hatchery fish breed with wild fish and introduce traits that may not be suited to a particular stream. Genetics most likely determine such traits as the timing of smolting, disease resistance, temperature tolerance, size of eggs, size of fish, timing of return, and possibly the ability of a salmon to find its natal stream. Because the brood stock for hatcheries are often obtained from distant watersheds, hatchery salmon may not be genetically suited for rivers near the hatchery. Hatchery fish which stray to local streams and spawn with wild stocks might introduce traits that would reduce the ability of wild salmon fry to survive in their natal stream.

During the 1970s, when Alaska's current hatchery program began, some biologists expressed concern about the risk to wild salmon of large numbers of hatchery salmon.⁸ These concerns have been amplified in recent years. Several scientific conferences have convened to discuss the interactions of wild and hatchery salmon. A recent article by the American Fisheries Society's Endangered Species Committee identifies 159 West Coast salmon stocks at risk of extinction and 54 additional stocks of special concern (Nehlsen et al.

⁷Attempts to develop natural runs of coho, chinook, and sockeye salmon in Japan have been unsuccessful.

⁸The Alaska District of the American Institute of Fishery Research Biologists issued a position paper concerned with genetic implications of hatcheries in 1975 (Attachment A). This organization was concerned that legislation creating private, nonprofit hatcheries did not address genetic issues.

1991).⁹ Habitat loss, over-fishing, and negative interactions with hatchery fish were cited as the major threats to the wild stocks. The article notes that there is a high probability that 104 of these wild stocks have suffered genetic changes from the presence of hatchery fish.

Although researchers have recently placed more emphasis on studying the possible impacts of hatchery salmon on wild salmon, scientists debate the results of these studies. Many factors could be responsible for the decline of a salmon stock. Weak runs may result from habitat disturbance, over-fishing, disease, competition with other fish, or unsatisfactory environmental conditions, as well as a reduction in fitness from the influence of hatchery fish.

Even when evidence suggests that hatchery fish may have adversely affected a specific wild stock, it is difficult to generalize from that evidence about other stocks. First, each species of salmon has a different life history, different lengths of time in freshwater and marine environments, and different preferences for habitat and feeding.¹⁰ Second, a study in one area may produce different results than if it was conducted in another environment or using different research methods. Third, the same study completed during separate years could have different results because of changing environmental conditions from year-to-year. Fourth, the location of a hatchery and its operating procedures will influence the effects of hatchery fish on wild populations. Fifth, the source of hatchery brood stock may determine the effect on local wild salmon. Sixth, different researchers may reach different conclusions from the same data. Lastly, there is often a shortage of baseline data on wild stocks (many significant stocks may not yet be identified), so it is difficult to measure changes that may occur.

Despite the gaps in scientific knowledge, there is consensus on at least two major points. First, fishery experts agree that in mixed stock fisheries where there are strong hatchery returns and weak wild stocks, wild stocks are likely to be over-harvested. Second, fishery geneticists generally agree that hatchery salmon have the potential to alter the genetics of wild fish. Researchers do not agree, however, if interbreeding between hatchery and wild fish will reduce the long-term fitness of wild salmon stocks. Likewise, there is not a consensus about how hatchery fish affect wild fish through competition, transmission of disease, and predation. Large-scale releases of hatchery salmon, however, are more likely to result in more profound effects on wild salmon than are releases of smaller numbers of fish.

⁹Salmon stocks in California, Oregon, Idaho and Washington were examined in this study.

¹⁰Reimers (1979) reports that life histories of juvenile chinook salmon vary both within and among stocks although many managers fail to recognize such variation.

GENETIC DILUTION OF NATURAL FISH STOCKS BY HATCHERY-PRODUCED FISH

The genetic diversity of wild salmon populations in Alaska is the result of ten thousand years of natural selection.¹¹ Biologists assume that specific salmon stocks are best suited to their immediate native environment and that wide genetic diversity permits the stock to withstand extreme changes in environmental conditions. Wild stocks are "adapted to their local habitats, yet flexible enough to respond to future changes in these habitats" (Oregon 1990). The consensus among geneticists is that "fitness (reproductive potential) is enhanced by heterozygosity (genetic variability)" (ADF&G 1985, p. 14).

The subject of genetic dilution is further addressed under several subheadings: the lack of scientific consensus, evidence of reduced genetic variability, causes of reduced variability, interbreeding of hatchery and wild salmon, and evidence of a loss of fitness.

Lack of Scientific Consensus

While there is a general consensus among biologists that hatchery strays can affect the genetic make-up of wild fish, it is difficult to prove that such changes will reduce the fitness of a naturally spawning salmon stock. Kelly et al. (1989) surveyed salmon experts and found no "solid data base which could support a documented position (either pro or con) regarding the effects of interbreeding among wild and hatchery fish" (p. 83). Waples et al. (1990) state that compared to other management problems, there has been little effort to address the genetic aspects of salmon management. The current state of scientific knowledge is unable to bridge the gap between the ardent proponents of aquaculture and those who recommend a more cautious approach. Chettleburgh (1991) states that genetic pollution

has become a rallying point for the opponents of aquaculture, particularly commercial fishermen and environmentalists who use the issue with impunity since it is almost impossible to prove or disprove. The effects, if any, may take centuries to occur. (p. 3)

Many scientists agree that literature on genetic impacts is not conclusive and "is largely speculative in nature and without much hard evidence" (Smoker 1985, p. 3). Poor returns can be blamed on over-fishing or bad environmental conditions (Helle 1981). Yet the increased attention given to the topic during the past few years reflects a growing concern by fisheries managers and

¹¹Two levels of genetic variation occur: differences between fish of the same stock and differences between different stocks (Oregon 1990).

scientists.¹² Those who encourage a conservative approach point out that loss of genetic variability that has evolved for thousands of years may be irreplaceable.

While some scientists are critical of hatcheries because of a fear that they may reduce fitness by altering genetic diversity, others are willing to accept some risks as long as production is increased (Mathisen 1991). As a result, different jurisdictions approach salmon enhancement from different perspectives. For example, while the Alaska Department of Fish and Game (ADF&G) Genetic Policy gives priority to wild stocks, Japan gives priority to enhanced fish.

Evidence of a Reduction in Genetic Variability

Several methods are used to determine the difference between hatchery and wild fish, including scale pattern analyses and starch gel electrophoresis of tissue proteins. Periodic genetic monitoring using electrophoresis can determine if there has been a change in allelic frequencies and therefore a reduction in genetic variability. These studies can reveal if there has been gene flow between a hatchery and wild population and if the genetic variability has been reduced. This process, however, does not reveal if hatchery-wild hybrids are more or less fit than the wild fish. In other words, geneticists can use electrophoresis to determine if a fish is a hatchery fish or a wild fish or if salmon stocks, such as hatchery fish, have lost genetic variability (assuming that the test recognizes a genetic difference between hatchery and wild fish and that electrophoresis data is available for the stocks before hatchery fish entered the gene pool).¹³ With salmon stocks that do not show a discernable difference using electrophoresis, it may be necessary to use a marking program such as coded wire tagging to determine if hatchery fish are spawning with native fish.

Researchers from around the world have found a reduction of genetic variability in enhanced salmon. In Ireland, Whelan and McGinnity (1991) found that a rare allele has been lost in hatchery fish. Japanese researchers found that concerns about a reduction of genetic variability are supported by a decrease in the number of late run chums and odd-year pinks, reduction of variations in

¹²The 1980 FAO-UNEP Expert Consultation on the Conservation of Genetic Resources of Fish, sponsored by the United Nations, was one of the first major conferences to deal with this topic. Several recent conferences include the April 1990 conference in Loen, Norway; the June 1990 NATO-sponsored Genetic Conservation of Salmonid Fishes in Moscow, Idaho; and the International Symposium on Biological Interactions of Enhanced and Wild Salmonids in Nanaimo, British Columbia. Dr. Ole Mathisen is planning a workshop on this topic to be held in Alaska this fall, and Dr. Tony Gharrett is organizing a panel discussion at the November 1991 meeting of the Alaska Chapter of the American Fisheries Society.

¹³According to Steer et al. (1991), there is a scarcity of data for wild stocks compared to enhanced fish.

the timing and duration of maturation of individual fish, and a reduction in the proportion of the effective number of breeding to total number of returning fish (Kaeriyama 1991). A Soviet Far East study of the Ochepukha watershed found that although selected breeding practices reduce the genetic potential of the hatchery salmon, researchers have not been able to detect any significant differences in abundance, size, weight or fertility of males between streams with only natural runs and those with both wild and enhanced stock (Shubin and Kaevo 1991). Ryman and Stahl (1981) report strong evidence suggesting that hatchery fish in Scandinavia have drastically changed the genetic composition of wild brown trout.

Causes of Reductions in Genetic Variability

Hatchery practices can lead to a reduction of genetic variability. For example, poor hatchery management could reduce the genetic variability through inbreeding or as a result of inadvertent or purposeful selection.

Inbreeding

Crossing salmon that are directly related to one another can result in a loss of genetic variability known as inbreeding. According to Smoker (1985),¹⁴ studies have shown that inbreeding is a distinct possibility in a hatchery. Practices such as the use of a low male to female ratio or too few fish for brood stock may increase the possibility of inbred fish in future generations. The use of local wild stocks to periodically refresh hatchery populations is one way to avoid inbreeding. Studies have not yet documented inbreeding for Pacific salmon hatchery stocks. Riddell et al. (1991), however, speculate that inbreeding could account for reductions in body size of cohos. Waples et al. (1990) note that there have been no comprehensive attempts to determine if hatcheries have been successful in their attempts to prevent inbreeding. Inbreeding depression (loss of vigor) has been documented for some hatchery-raised trout species and Atlantic salmon (Kelly et al. 1989). This may be the result of using a small number of fish to start these hatcheries.

Additionally, studies have not documented a reduction in the average heterozygosity of a Pacific salmon hatchery stock when compared to the whole species (Kelly et al. 1989, Smoker 1985).¹⁵ A lower value of heterozygosity

¹⁴Smoker (1985) reports that a study has shown that with 50 spawners, a hatchery would lose 10 percent variability after ten generations and 25 percent after 20 to 30 generations.

¹⁵Unless studies have been completed for wild fish before genetic interaction with hatchery fish, comparing average heterozygosity of hatchery fish to that of "wild" fish may not be valid.

in Japanese chum salmon when compared with U.S.¹⁶ chum salmon suggests a loss of genetic variability for chum salmon in Japan.

Selection

The rate of genetic change may increase dramatically in hatcheries through selection, which may be either deliberate or unintentional. Selection of large males and earlier-run salmon for hatchery brood stock has resulted in earlier runs of Sakhalin Island chum salmon. The fish are bigger but the rate of reproduction has decreased (Khorevin 1991). Larkin (1981) suggests that a change in traits of hatchery salmon is likely and selection over generations may explain a perceived decline in the fitness of hatchery stocks.

Some scientists recommend against intentional selection for hatchery fish for specific characteristics such as size, growth, and color (Krueger et al. 1981). The ADF&G's Genetic Policy recommends that brood stock represent a broad cross section of the genetic diversity of a run. However, Larkin (1981) suggests that selected hatchery stocks could improve wild stocks and that the "truth may well be that wild stocks improve hatchery strains rather than that hatchery strains dilute wild stocks" (p. 1473). He suggests that deliberate selection could also offset selection by the fishery, perfect transplanting techniques, and determine the timing of hatchery runs. Smoker (1985) also suggests that hatchery salmon could increase genetic diversity in stocks that have been decimated through over-fishing or as a result of natural population crashes. This is because a small escapement of such a stock could lead to inbreeding.

Actions of hatchery personnel or hatchery conditions may result in inadvertent selection. Hatchery-produced salmon may adapt to hatchery conditions which differ from conditions in the wild. To avoid selection of fish tolerant of hatchery conditions Krueger et al. (1981) recommend release of fish at an early age.

Spawning behavior in the wild involves an elaborate courtship ritual and an establishment of a hierarchy of males. Pink salmon tend to mate with similar sized mates and these progeny tend to be more viable than matings between fish of different sizes, as often occurs in hatcheries (Chebanov 1991). Thus, even random pairing of hatchery fish are likely to produce different pairings than what would occur naturally (Helle 1981).

Natural selection in hatcheries produce fish adapted to hatchery conditions which may not have survived in freshwater conditions (for those salmon that do not migrate immediately). If these salmon survive ocean conditions, they could stray to local streams and if successful at reproduction they could reduce fitness.

¹⁶Japanese fisheries are almost completely dependent on hatchery production.

Interbreeding of Hatchery and Wild Fish

The increased straying of hatchery salmon, especially transplanted fish, can result in the transfer of ill-adapted genes. Large-scale hatcheries can be expected to have more strays than small-scale hatcheries (Smoker 1985).

Although it is known that salmon will stray to some degree, scientists do not agree about the degree straying occurs. We were unable to find many studies that predict a specific percentage of strays for either wild, hatchery or farmed salmon.¹⁷ Gritsenko (1991) found that there is a significant increase in spawners due to straying from large rivers in the Okhotsk Sea coast of Sakhalin Island, but that there is poor survival of their progeny. Using a mathematical model, Zhivotovsky et al. (1991) found that straying between stocks had a significant influence on the dynamics of pink salmon populations. On the other hand, an Alaska study at Auke Creek suggests that pink salmon do not ordinarily stray in large numbers to nearby streams, and that there may be some degree of genetic isolation between runs that spawn at different times in the same stream (Gharrett and McGregor 1991). Other studies may not consider that pink salmon are known to test various streams before ultimately spawning in their natal stream (Gharrett, personal communication). Therefore, the extent of straying suggested by some researchers may be exaggerated.

Many authors report that transplanted and hatchery salmon stray more often than wild salmon. Helle (1981) reports that transplanted salmon have a reduced homing ability. Waples et al. (1990) think that straying rates may be higher for hatchery fish. Gausen and Moen (1991) found that greater numbers of escaped farm salmon spawn in rivers within twenty kilometers of a net pen facility. Bams (1976) conducted an experiment in British Columbia using transplanted pink salmon, hybrids of transplanted males and wild females, and wild salmon. He found that for a stream in British Columbia, transplanted salmon were the least likely to return to spawn. The hybrids were more likely to return, but the wild salmon had the best chances of returning. In a similar experiment, Smoker (1985) found that transplanted salmon may be more fit than transplanted-wild hybrids. The propensity of transplants to stray may mean that genetics play a role in the ability of pink salmon to return to their natal streams. Larkin (1981) suggests that the straying of hatchery fish may be due to rearing conditions instead of or in addition to genetics.

Although hatchery salmon may stray more than wild salmon, Soviet scientists Gritsenko and Kovtun (1991) think that locating a hatchery away from natural spawning areas can reduce straying and the impact of straying on the gene pool of wild stocks. The authors maintain that wild and enhanced fish can co-exist as two reproductively isolated groups.

¹⁷A 1991 study by Hard and Heard that studied chinook returns from a fish hatchery in Little Port Walter that used transplanted salmon. Of the 1.1 percent of the fish that strayed, approximately 1/3 of them strayed within 7 kilometers, almost 2/3 strayed less than 25 kilometers, and the most distant stray was 500 kilometers away. Curiously, none of them strayed to their original rivers which were 250 kilometers from the hatchery.

The ADF&G Genetic Policy acknowledges the potential of straying hatchery fish to reduce the fitness of the naturally spawning fish, but it also suggests that hatchery strays may have little impact on wild stocks.

The degree of interbreeding between hatchery and wild fish can only be detected if there is a significant genetic difference between the two. Studies have revealed little contributions by hatchery steelhead fish to wild fish in the Skagit River after twenty years of stocking. On the Yakima River, considerable introgression (introduction of genetic material from one gene pool to another) between hatchery and nonanadromous wild steelhead occurred, yet anadromous steelhead have shown little introgression with hatchery fish (Campton 1991). Hindar et al. (1991) cite several other studies that reveal introgression between hatchery or farmed salmonids and wild stocks.

Evidence of a Loss of Fitness

Some studies have shown that hybrids of wild and nonlocal salmon are less fit than their wild counterparts (Waples et al. 1990). Because many traits are thought to be inherited, biologists fear that hybrids will be less able to compete, less resistant to disease, and more vulnerable to predation. Allendorf (1991) points to the growing evidence of a loss of local adaptations. Larkin (1981) reports that some people suspect that declining success of hatcheries after a decade or so may be due to genetic changes. Hindar et al. (1991) state that a "considerable body of relevant indirect evidence" points to adaptive changes resulting from interbreeding (p. 950).

On the other hand, according to Kelly et al. (1989), some fishery specialists do not think that hatchery-wild hybrids will detrimentally affect wild stocks. Additionally, there is speculation that in some cases of over-fished wild salmon stocks, hatchery fish may actually increase the fitness of the wild stocks (Kelly et al. 1989; Larkin 1981). However, according to Davis and Burkett (1989), "[a]ny loss of genetic variation results in a loss of fitness, but any gain in genetic variation may or may not improve fitness" (p. 4).

Some researchers have found that wild smolts are more likely to survive than hatchery smolts (Hilborn et al. 1991; Whelan and McGinnity 1991). Swain and Riddell (1991) suggest that if hatchery fish mate with wild stocks, the offspring may be less fit than the wild fish, but that throughout time, wild fish stocks would likely regain fitness.

A study in Norway found that farmed brown trout males do not survive well in wild streams and that only a limited amount of spawning occurred between wild males and farmed females (Skaala et al. 1991). Flemming and Gross (1991) found similar results with hatchery-reared coho salmon in Vancouver Island, British Columbia. Hatchery salmon, especially males, did not reproduce well unless there were no fish in the stream. As the density of spawners increased, the reproductive success of the hatchery fish decreased. Hatchery fish that do breed in the wild could produce a genetically inferior fish. Reisenbichler and McIntyre (1977) revealed that hatchery steelhead were genetically different from wild steelhead and that they did not survive as well as wild fish.

Some studies using hatchery and wild fish from the same parents have found that the hatchery fish do not survive as well as wild fish in natural conditions. These results suggest that a reduction in fitness is a response to hatchery conditions rather than caused by genetics. A study using progeny of the same parents reared one group naturally and the other in the hatchery found that the hatchery group had a reduced osmoregulatory ability (i.e., diffusion of water through cell walls). Because both came from same stock, the difference was probably a response to the rearing environment (Shrimpton et al. 1991). Ward et al. (1991) found that pen-reared steelhead from wild parents survived at lower rates than wild steelhead.

Transplants

Hatchery salmon bred from salmon transplanted from long distances have a greater chance of being less fit than those bred from a local stock. The ADF&G Genetic Policy assumes that hatchery stock from a different geographic area could reduce fitness of a salmon stock, but it is not known if this reduction is critical (Davis and Burkett 1989). The policy suggests that it may be safe to transfer stocks from within the same region for brood stock (ADF&G 1985).

Many states, including Alaska, restrict the transport of live fish or gametes (eggs or sperm) to decrease the chance of spreading disease and to be sure fish used in hatchery operations are similar to local stocks. Recently, however, an increase of fish smuggling by aquacultural operators was reported in California (CAA 1990).

INCREASED FISHING PRESSURE ON WILD STOCKS

In a survey of fishery professionals about the effect of hatchery fish on wild fish, Kelly et al. (1989) found that the greatest consensus was that large-scale releases of hatchery fish can be detrimental to wild fish stocks if there is no feasible way to separate the fish before harvest. "Almost all hatchery-produced salmon in Alaska have the potential for engendering mixed-stock fishery management problems" (Smoker 1985, 14). Mixed stock fisheries are difficult to manage because there is a danger that the smaller stocks will be over-harvested. The state's mixed stock policy encourages terminal fisheries whenever possible (fisheries that occur after the stocks separate). It is not economically feasible to fish at many terminal fisheries because once salmon near their spawning area, the quality of their flesh declines as they adopt spawning characteristics.

While there is danger of over-exploitation of a weak stock in mixed stock fisheries, the problem is compounded with the addition of hatchery stocks (Smoker 1985). Hatchery stocks need less brood stock than wild fish, so it is

possible to have a higher harvest rate for hatchery fish than for wild fish.¹⁸ Especially with large-scale hatcheries, it is difficult to estimate the numbers of wild fish returning (unless they are separated physically or at the time of return). A certain number of wild fish are needed to sustain a stock's genetic variability.

The director of ADF&G's Division of Commercial Fisheries in 1982 explained that with fisheries enhancement, "[w]e may not be able to fully develop some sites and stocks without declines 'n natural stocks or foregoing harvests of enhanced stock unless we modify our current way of managing" (Pennoyer 1982, p. 113). Under mixed stock fisheries "stocks which are of consistently lower productivity will probably have consistently lower escapements and sooner or later will decline, often drastically, even with 'good management'" (Pennoyer 1982, p. 112).

Many examples document that optimum harvest of hatchery fish in mixed stock fisheries has occurred at the expense of wild fish. Because hatchery fish can withstand a higher exploitation rate than wild fish, wild stocks will be over-harvested unless the entire fishery is limited (Waples et al. 1990). An Oregon study found that the decline in abundance of wild coho salmon in the Columbia river coincided with a sharp increase in harvest rates. The study suggests that current harvest rates will result in the extinction of wild coho (Cramer 1991).

In the Baltic Sea, the number of natural Atlantic salmon drastically declined as a result of an off-shore fishery on mixed stocks (Eriksson and Eriksson 1991). Hilborn (1990) reports that high harvest rates of hatchery fish in the waters between British Columbia's Vancouver Island and the mainland has resulted in an increase in hatchery production, a decline in wild stocks "and the Canadians have no more coho now than they did fifteen years ago" (p. 3). Enhancement activities (new spawning channels) in Babine Lake of British Columbia's Skeena River basin significantly increased production at the expense of other basin stocks (Smoker 1985).

The risks inherent in mixed-stock fishing may be reduced if hatchery and wild fish spawn at different times. Although original hatchery stocks in Prince William Sound were selected to be later or earlier than the wild runs, there is some overlap. Wild stocks can be easily over-harvested at the entrance to the sound in areas where stocks are mixed, such as happened during 1990 (Geiger et al. 1991). According to Eggers et al. (1991), the recent decline in wild pink salmon in Prince William Sound is believed to be a result of low escapement due to over-fishing of wild stocks. Hatchery and wild stocks are harvested together "in the near-terminal mixed-stocks fishing areas and as cost

¹⁸Optimum harvest rates for hatchery fish are 90 to 95 percent while optimum rates of harvest for wild fish are between 60 to 75 percent (Kelly et al. 1989). Hatchery production results in fewer mortalities than wild production because wild fish are subject to changing environmental conditions, competition and disturbance of redds by other fish.

recovery in the hatchery terminal harvest areas" (p. 4). The authors ascribe the low escapement of wild fish to "a weak implementation of the fixed escapement goal policy" (p. 27). In other words, in order to harvest the high numbers of hatchery-reared salmon before they lose quality, harvest rates of wild salmon in these fisheries have reduced the number of wild salmon escapement to levels lower than before the hatcheries were built.

To assess the pressure exerted upon wild fish, some method of identifying the numbers of wild and hatchery salmon must be used. Coded wire tags are sometimes inserted in juvenile fish. The coded wire tag program in Prince William Sound, however, doubled the cost of managing that fishery. A recently introduced marking method, known as thermo-marking, relies on distinctive markings on the fish's otolith (ear bone) as a result of different water temperatures in the hatchery. Each hatchery using this method uses a different sequence of water temperatures. Electrophoresis is another technique that can be used to separate stocks, although it has limitations. The lack of a marking program for hatchery fish from the Gastineau hatchery in Juneau made it impossible to determine if poor returns in 1989 were due to over-harvesting (Geiger et al. 1991).

Smoker (1985) recommends several possible solutions to reduce over-fishing of mixed hatchery-wild stocks: 1) identify the percentage of wild fish in the mixed-stock fishery and reduce catch levels to permit sufficient escapement of the wild stocks, 2) establish annual catch quotas for the fishery, 3) use hatchery stock that return at a different time than wild fish, and 4) restrict the numbers of hatchery fish produced. Smoker acknowledges the problems with each of these solutions.

COMPETITION FOR FOOD BETWEEN WILD AND HATCHERY-PRODUCED FISH

The issue of carrying capacity (the number of fish that can be supported in a given area) of salmon is still contentious. Inhibited growth of salmon due to competition with other fish is known as density-dependent growth. It is difficult to determine if density dependency is the cause of a reduced average size of salmon or if this reduction is a result of poor environmental conditions (e.g., less food sources due to colder water temperatures), or a combination of factors. It should be noted that even if density dependency is found to be an important factor in one area, it may not be as important in another area or at another time. Environmental conditions may be different during different years and in different places. Also, salmon of the same species may have different migration patterns in different areas.¹⁹ Different

¹⁹In the Soviet Far East, salmon from East and West Kamchatka spend about three months in coastal waters while those in southwestern Sakhalin Island spend up to five months in coastal waters (Karpenko 1991).

life histories of Pacific salmon species makes it difficult to generalize about density-dependency factors for all salmon.²⁰

According to Peterman (1984), "[d]ensity-dependent growth or survival has been well documented for the freshwater life phase of Pacific salmon," but less is known about such limitations in marine waters. Given the lack of knowledge of density-dependent growth among wild fish, it is even more difficult to determine how important competition between hatchery and wild fish is. Many scientists suspect, however, that hatchery and wild salmon may compete for food in freshwater, in estuaries, in saltwater nearshore areas, and in the open ocean. Hatchery fish may also displace wild fish from their habitat during juvenile freshwater residence and during spawning (Hindar et al. 1991). Additionally, Kelly et al. (1989) report that some scientists believe that hatchery-wild hybrids may be less able to compete with other fish for food. The density-dependency dispute will only be answered by studies that span many years and consider a variety of factors including fluctuations in environmental conditions and the numbers of hatchery fish released. The discussion below centers on existing studies on this subject.

Competition in Freshwater

A Washington study in two rivers suggests that hatchery coho fry were better able to compete than wild fry. The production of hatchery fry increased, but the total number of fry living to smolts stayed the same. While the number of hatchery smolts increased, the number of wild smolts decreased (Seiler et al. 1991). Reisenbichler and McIntyre (1977) also found that hatchery fish released into stream systems may affect wild fish through competition for food and space. Lichatowich and McIntyre (1987) report that hatchery coho smolts displaced wild fry. Another Washington study, however, found that neither wild nor hatchery coho (from native stock) fry were affected by the presence of the other when released into four streams (Wampler et al. 1991). A study in France showed that if prey density is low, coho salmon escaped from farms could affect the density and growth rate of native Atlantic salmon (Beall and Heland 1991).

Competition in Estuaries

Some evidence points to density dependence in estuaries. Larkin (1981) notes that the unnaturally high numbers of hatchery salmon released at one time may displace wild fish at the site of release as well as in the estuaries and offshore rearing areas. Preliminary research in British Columbia estuaries reveals that migration of large numbers of hatchery-raised sockeye smolts may affect the growth and distribution of wild chinook fry in some estuaries. The researchers suspect that the limitations in the estuary may be due to space and food (McAllister and Levings 1991).

²⁰For example, pink and chum salmon immediately migrate to salt water and do not have competition pressures in freshwater. On the other hand, sockeye coho salmon may spend several years in freshwater and are therefore subject to different types of competition.

Competition in Nearshore Areas

Ocean survival may depend on nearshore competition. Bob Burkett, chief of technology and development for the FRED division places a high priority on studies concerning the nearshore carrying capacity (Gay 1991). Some salmon spend the early portion of their marine life in nearshore areas. Ivankov and Volkov (1991) found that competition for food is an important factor in early marine life survival for juvenile salmon. Karpenko (1991) found that the availability of food, determined in part by the numbers of juveniles, is a major factor determining survival of juveniles. An Oregon study that involved the review of demographic records of salmon stocks suggests that the carrying capacity of nearshore areas may be exceeded during some years. However, according to Smoker (1985), other authors have interpreted the same data and reached the opposite conclusion.

Eggers et al. (1991) acknowledge that it is possible that the nearshore carrying capacity of Prince William Sound may be nearly reached, but there "does not appear to be any competitive interaction between hatchery and wild stocks" (p. 23). Some people speculate, however, that the reduced size in salmon during the 1991 season was due to competition as a result of high hatchery production (Miller 1991).

Competition in the Ocean

Studies suggest that there may be density-dependent growth in the Gulf of Alaska. Peterman (1984) revealed that significant reductions in body sizes of adult sockeye salmon occurred during years of high numbers of sockeye salmon in the Gulf of Alaska. This study suggests that growth in the gulf is slowed during early ocean life and most likely results from "competition for food among similar-sized sockeye."²¹ Eggers et al. (1991) report that a trend in decreasing average weight suggests that pink salmon growth in the Gulf of Alaska may also be density dependent, affected in part to increasing hatchery returns.

Studies in other parts of the world also suggest a relationship between high numbers of salmon and reduced growth. A Japanese study found that during the last decade of increased chum salmon hatchery production, salmon have decreased in size along with a decrease of the mean age at maturity. Stunted growth during the first year in the ocean suggests that the rate of growth decreased because of increased numbers of fish competing for food (Hayashizaki and Hitoshi 1991). Kaeriyama (1991) also suggests that a reduction in size and average age of adult chum results from density-dependent growth, but found little evidence that survival has declined (Kaeriyama 1991).

²¹According to Peterman (1984) 80 percent of the sockeye in the Gulf of Alaska are from British Columbia and Bristol Bay. The density-dependent growth appears to be between fish of the same stocks as well as among sockeye from different origins.

Smoker (1985) modeled factors affecting ocean survival and found that large releases of hatchery salmon could not only result in a reduction of survival and growth but also could lead to increased variability of salmon abundance from generation to generation. While salmon may have more food available than they need in many areas, food may be patchy during their first summer at sea and "transitory limits to carrying capacity" may be important. Production of salmon has been more variable as hatchery production has increased in Hokkaido Island, Japan and in Oregon (Smoker 1985).

Ricker (1981) notes a decrease in the average size and age of Pacific salmon since the 1920s. He attributes this decrease to eight possible causes, including the possibility that some aspect of artificial propagation has caused slower growth.

Other studies suggest that density-dependent growth is unlikely. Smoker (1985) reports several studies that show no evidence that ocean growth is limited by density of the salmon. One of these studies simulated the growth and survival of salmon during the first six months of ocean life and found that more food is available to Pacific salmon than is consumed.

Should nearshore density-dependency growth be a threat, possible solutions include staggering the release of stocks and rearing salmon to a larger size before release. Future monitoring of growth, age and survival records will help determine where density-dependent growth appears to be a problem.

PREDATION ON WILD STOCKS BY HATCHERY PRODUCED FISH

Little is known about predation by hatchery fish. Generalities based on individual studies are problematic because of differences in the life histories of different salmon species (e.g., differences in freshwater residency, time spent in nearshore areas and ocean migration patterns). While there is evidence of predation by hatchery fish on wild salmon, wild salmon also target hatchery fry.

Ivankov and Volkov (1991) found that predation was an important factor in early marine life survival for juvenile salmon. Most knowledge of predation is in freshwater, estuaries and nearshore areas, and few studies quantify the loss of wild salmon by predation of hatchery fish (Smoker 1985). Hilborn (1990) states that hatchery fish pose a possible threat to wild fish by predation upon them. Smoker (1985) also suspects that enhanced fish may prey upon wild fish. Correlations between releases of hatchery salmon and declines in wild stocks have been observed. Hatchery releases of coho have been found to be coincident with decreases in pink and chum stocks in Washington. In another part of the state, delaying the release of hatchery coho until pink salmon migrated resulted in greater survival of pink salmon (Smoker 1985).

Coho salmon raised as smolts are known to feed on hatchery-produced pink salmon, and early predation in estuaries may be heavier than later predation. Additionally, large numbers of hatchery-released fry may attract coho salmon, which will feed on hatchery as well as wild salmon fry (Smoker 1985, Hindar et al. 1991).

Wood et al. (1991) found that declining sockeye returns to four lakes on Vancouver Island, British Columbia, were not a result of predation by hatchery smolts during the downstream migration. The researchers suspect that marine survival may be affected by predators attracted to nearshore areas because of the large numbers of juvenile salmon present there.

Karpenko (1991) reports that mortality of salmon due to predation varies from 1.5 to 52 percent in coastal waters of various regions. Fish, birds and marine mammals feed on juvenile salmon, but other species of fish (e.g., smelt, Arctic char and Siberian Char) are the most significant predators. Predation was found to be highest during the peak period of downstream out-migration for pink and chum salmon.

Some authors report predation upon hatchery fish as a reason for a reduction in hatchery fish. Beamish and Thomson (1991) report that in the Strait of Georgia, British Columbia, the average survival of hatchery coho and chinook were initially higher than that for wild fish, but after five years the survival rate decreased below historic levels for wild fish. The authors speculate that the cause of the decline in the survival rate may be due to a cyclic decrease in other food for predators so that they target hatchery fish. A Washington study suggests that hatchery fish may be more vulnerable than wild fish to predation by squawfish although the researchers concede that the higher predation may be because the hatchery fish were the most abundant prey (Fresh et al. 1991). One laboratory revealed that under pressure of predation hatchery chum had reduced feeding when compared to wild chum (Tompkins 1991).

THREAT OF DISEASE FROM HATCHERY-PRODUCED FISH ON WILD STOCKS

The threat of disease and parasites is twofold. First, a possible reduction of genetic diversity resulting from interbreeding with hatchery fish could make a natural population of salmon more susceptible to disease. Second, diseased hatchery stock could transmit the illness to wild stocks.

Few studies document the transmission of disease between hatchery and wild fish. However, Kitchell (1991) reports that hatchery-transmitted diseases may have led to the death of thousands of salmon in the Great Lakes. In a California hatchery, an unintentional cross between chinook and coho resulted in a hybrid that may have resulted in the first outbreak of IHN in coho (a viral disease lethal to hatchery chinook not normally found in coho salmon). None of these crossbreeds have been found returning to a hatchery, however (Bragg 1991). The ADF&G fisheries pathologist Ted Meyers knows of no instances in Alaska where hatchery fish have transmitted diseases to wild fish (personal communication). The ADF&G policy about the control of disease prescribes methods to reduce the transmittal of disease from hatchery-fish to wild fish (Attachment B).

The use of transplanted fish from one area to another can increase the chance of disease outbreak in the wild fish. For example, 23 wild stocks in Norway were decimated after the introduction of fish from the Baltic spread a parasite (Menke 1990). Smoker (1985) reports that researchers in Oregon speculate that transplanted coho may have weakened the ability of wild coho to resist the

pathogen *Ceratomyxa shasta* in Nehalem Bay. Although transplanting fish from outside of Alaska is prohibited now, during the 1970s out-of-state chinook stock were raised in Ketchikan's Crystal Lake hatchery and in the Dredge Lake area in Juneau. The ADF&G terminated this project after the IHN virus infested the transplanted chinook salmon (Burkett, personal communication).

Captive fish are more susceptible to disease because of stress caused by the hatchery environment (FFTF 1990). There is some speculation that hatchery-wild hybrids may be less resistant to disease than wild fish (Kelly et al. 1989).

OTHER EFFECTS

Hatchery salmon may affect wild salmon in other ways not addressed above. Some professionals theorize that wild fish may follow hatchery fish as a result of a chemical (pheromonal) attraction (Kelly et al. 1989). A detrimental effect of hatchery salmon may result when late-spawning hatchery strays dig up the redds of the wild fish (Menke 1990). Additionally, in Pacific Northwest states some hatcheries that fail to produce adults must use wild stocks for a source of eggs and thereby present a net drain to already dwindling numbers of wild stocks (Hilborn et al. 1991). Over-exploitation of wild brood stock for a hatchery on Sakhalin Island in the Soviet Far East also resulted in destroying chum salmon runs from small brooks of the Tym River (Gritsenko and Kovtun 1991).

Recent experiments with gene transfer techniques could someday be used in commercial salmon hatcheries to produce faster-growing fish or ones with greater environmental tolerance. The American Fisheries Society has recommended that such fish not be used in aquaculture facilities without completion of risk assessment studies (Kapusinski and Hallerman 1990).

An additional consideration relates to the effect large unharvested returns of hatchery salmon may have on wild salmon. During the 1991 season, a significantly large return of hatchery pink salmon returned later than normal but matured earlier than normal. As a result of market saturation, millions of these fish were not harvested. The effect of this large unharvested return is unknown and a few questions remain unanswered. Did hatchery fish displace wild salmon in local streams? Will there be a subsequent reduction of wild salmon in future years? Will there be a larger number of hatchery-wild hybrids? Although there are no funds allocated to study these questions, tissue samples from Prince William Sound rivers are being preserved for possible study in the future.

HATCHERY MANAGEMENT IMPLICATIONS FOR WILD SALMON

Proper siting of a hatchery along with good hatchery management and effective management of the commercial fisheries will reduce the potential for adverse biological interaction between hatcheries and wild fish. Conversely, improper siting and poor management practices will increase the risks of adverse interaction. The following discussion considers the effects of management in

general and then provides an overview of management programs in Alaska and Pacific Northwest states.

Sound Hatchery Management Practices

According to Helle (1981), the location of a hatchery is the most important factor that will help maintain wild populations. Hatcheries must be able to separate wild and enhanced stocks either through time or space. General consensus among biologists is that large-scale hatcheries can potentially wield more damage to wild stocks than smaller facilities. Larkin (1981), however, notes that in some cases large centralized hatchery facilities may be practical.

Other potential problems resulting from hatcheries may be minimized by following specific procedures. The risk of losing genetic variability in hatchery salmon can be reduced by using a large founder population, random pairing representing a wide cross section of the local run, avoiding intentional selection, and crossing wild and hatchery fish every season (Kelly et al. 1989). Although there is no official policy for renewing hatchery stocks Menke (1990) claims that

Alaska fisheries officials agree that it may be a good idea to renew hatchery production with wild eggs and sperm on a frequent cyclic basis, perhaps every four years or so (p. 50).

Some scientists recommend that wild salmon mating behavior be emulated as much as possible (e.g., use as high a ratio of male to female fish as occurs in the wild). Hatchery and wild fish can be kept genetically similar by initially using local brood stock and by periodically renewing hatchery stock with local fish.

Maitland et al. (1981) recommend the establishment of a worldwide system to identify and monitor wild salmonids. They suggest that a group such as the International Union of Nature and Natural Resources (IUCN) undertake this project. Others advocate the creation of areas known as genetic sanctuaries to protect significant salmon stocks. Enhancement activities would be prohibited in these areas (FFTF 1990; Helle 1981, ADF&G 1985).²²

Waples et al. (1990) recommend that programs be expanded to identify different genetic stocks, monitor genetic changes in hatcheries, and evaluate the consequences of proposed large-scale enhancement programs. Kelly et al. (1989) recommend meticulous record keeping for hatcheries about such topics as breeding practices, disease resistance and average heterozygosity. Use of recently developed thermo-marking techniques may eventually make it feasible to mark all hatchery fish and determine the extent to which salmon stray.

²²No gene bank programs for salmon are officially recognized in the U.S. (Kelly et al. 1989).

Other management initiatives may become important in the future. Release of sterile hatchery salmon may be used to prevent hatchery fish from affecting the gene pools of wild stocks.²³ Sperm from fish can be stored (cryopreserved), but preservation of eggs or embryos has not yet been accomplished (Thorgaard and Cloud 1991).²⁴ Wildt and Rall (1991) warn that such techniques should not be used as a "quick-fix" but instead be used along with other conservation techniques. Norway's gene bank program involves the deep freeze of sperm and establishment of living gene banks in brook stock-stations. The program began in an effort to preserve genetic material before the genetic make-up of wild fish were negatively affected by fish farm strays (Gausen 1991). Gene banks have also been established in the Soviet Union (Helle 1983).

A paper by the American Fisheries Society recommends federal regulation of salmon and steelhead hatchery programs to preserve existing genetic diversity (Nehlsen et al. 1991). The authors think that federal regulation now could reduce future listings of stocks as required by the Endangered Species Act.

Alaska Hatchery Management

Because management can minimize or exacerbate the negative impacts of hatcheries, some discussion of Alaska statutes, regulations and policies is appropriate. However, a critique Alaska's hatchery program is beyond the scope of this memorandum.

The intent language of the 1974 legislation authorizing private nonprofit hatcheries reflects a priority for wild stocks.

The program shall be operated without adversely affecting natural stocks of fish in the state and under a policy of management which allows reasonable segregation of returning hatchery-reared salmon from naturally occurring stocks (Chapter 111 SLA 1974).

Alaska Statute 16.10.400 states that the ADF&G commissioner will not issue a hatchery permit unless the hatchery "would result in substantial public benefits and would not jeopardize natural stocks." Other statutes do not show a clear preference for management of wild stocks over hatchery salmon (White, personal communication; Utermohle, personal communication).

Alaska statutes direct ADF&G's Division of Fisheries Rehabilitation, Enhancement and Development (FRED) to complete state and regional plans. Alaska Statute 16.05.092(1) requires the FRED division to "develop and

²³Sterile triploid brook trout are recommended by Corely-Smith et al. (1991) to protect their genetic material. Triploid fish can be created by using heat treatments or by crossing tetraploid females with diploid males. Seeb (1991) reports that the British Columbia government is considering the use of sterile net pen fish to prevent escapees from spawning with wild fish.

²⁴Alaska is using sperm cryopreservation for fish on the Chilcat River (Seeb 1991).

continually maintain a comprehensive, coordinated state plan for the orderly present and long-range rehabilitation, enhancement and development of all aspects of the state's fisheries . . . and revise and update this plan annually." Alaska Statute 16.10.375 mandates the completion of comprehensive salmon plans by regional planning teams. State statutes also require each hatchery to complete an annual report including information about the brood stock used (AS 16.10.470).

The ADF&G regulations seek to minimize adverse impacts of hatcheries. For example, regulations specify that during the application phase for hatchery construction, regional planning teams review permit applications including provisions to protect natural stocks (5 AAC 40.170), a public hearing is held, and the department reviews the permit to be sure that hatchery returns will not "unreasonably or adversely affect management of natural stocks" (5 AAC 40.220). Regulations also mandate that hatcheries complete an annual management plan that outlines production goals, brood stock management and the management of the harvest of hatchery returns (5 AAC 40.840). A performance review is also required that evaluates the effect of the hatchery on natural stocks (5 AAC 40.860). Regulations require that a fish transport permit be obtained before transporting live fish within the state (5 AAC 41.005), and prohibit the importation of live fish from outside the state (5 AAC 41.070). Regulations also mandate disease control and inspection (5 AAC 41.310).

The ADF&G policies also address hatchery management. A 1982 draft manual of policies and procedures for the nonprofit hatchery program was never approved, but some of the policies were codified in regulation (ADF&G 1982). The Genetics Policy, is one of the most important current policies about hatcheries. This policy, a policy about disease and a policy about permitting nonprofit salmon hatcheries in Alaska are contained in Attachment B.

The ADF&G's Genetic Policy was created to "protect the genetic integrity of important wild stocks."²⁵ An eight-member team of public and private salmon experts produced the most recent version in 1985, but the policy is currently being reevaluated. The policy gives first priority "to protection of wild stocks from possible harmful interactions with introduced stocks." Comments by ADF&G officials have, however, indicated that preference could be given to

²⁵The Finfish Farming Task Force (1990) alleged that the policy is not always rigorously enforced and recommended that an ad hoc committee be appointed to assess compliance with this policy. The task force also recommended that guidelines in the policy be codified in statute.

hatchery stocks in certain situations.²⁶ The Genetic Policy also recommends that:

- stocks should not be transported between the large geographical areas of the state (no maximum distance is identified),
- donor stock should be physically similar to local stocks but local stocks are preferred,
- significant wild stocks should be identified, and watersheds with such stocks should only be stocked with progeny from indigenous fish,²⁷
- wild stock sanctuaries should be established where enhancement would be prohibited,²⁸
- a single donor stock should not be used for more than three hatchery stocks, and
- a minimum effective population of 400 brood stock should be used to develop and maintain hatchery stocks.

The second portion of the policy describes current knowledge and uncertainties about the effects of hatchery fish on wild fish.

The State of Alaska addresses the impact of hatcheries on wild stocks through statutes, regulations and policy, but some ADF&G commercial fisheries personnel have suggested changes. Geiger et al. (1991) recommend establishment of clear guiding principles for the hatchery program. The authors suggest that production-based objectives are in conflict with preservation of the genetic integrity of wild stocks and the reduction of fishing effort on specific wild stocks. Eggers et al. (1991) argue for an integrated management system "to

²⁶Kelly et al. (1989) report that the commissioner of ADF&G in 1981 stated that "... in some instances ADF&G would consider carrying out a program to purposely alter a wild stock for the benefit of a hatchery stock, provided circumstances indicate that the best interests of both the public and the resources would be served" (p. 30). The director of the Division of Commercial Fisheries in 1981 stated that "[c]onscious trade-offs of weak or smaller natural stocks may be justified by the magnitude of enhancement opportunity, but this cost must be carefully measured" (Pennoyer 1982, p. 113).

²⁷The team did not define "significant stocks" but instead left it to the Salmon Enhancement Regional Planning Teams to define this term. To date, significant stocks have not been identified.

²⁸At this time, there have been no formal designations of wild stock sanctuaries or conservation areas. A formal policy is currently being written that will outline procedures to establish such sanctuaries (Burkett personal communication).

meet dual objectives of protecting wild stocks and hatchery cost recovery/brood stock needs" (p. 30).

Wild Salmon Management in Other West Coast States

Severely depleted runs of wild salmon in Pacific Northwest states have prompted proposals to classify some of these stocks as endangered species. Fishery scientists there have a growing concern about the role of hatcheries in the depletion of natural runs. Accordingly, Oregon responded to the decrease in wild salmon by creating its Wild Fish Management Policy in 1990 (Attachment C).²⁹ The policy mandates that the Department of Fish and Wildlife identify all salmon populations (stocks) in the state. The policy also prescribes specific standards to protect wild salmon,

Other jurisdictions approach wild fish management in a variety of ways. Idaho gives first consideration to wild fish if there is a conflict between the two, and it gives priority to preserving genetic integrity over maximizing harvest potential. Washington has allocated 25 percent of Puget Sound for hatchery salmon, but the rest of the sound is managed for wild fish (Hindar et al. 1991). British Columbia classifies streams in three categories ranging from management for wild salmon (with some hatchery production) to streams managed for hatchery fish (Kelly et al 1991).

SUMMARY

The cumulative effect of habitat destruction, over-fishing and large-scale hatcheries has lead to the decimation of many wild salmon stocks in Pacific Northwest states. Biologists in states with a long history of hatchery programs are generally less enthusiastic about these programs than biologists in areas such as Alaska and British Columbia with comparatively recent programs. Although poor hatchery practices can clearly endanger wild salmon populations, scientists do not agree on the extent to which hatcheries with sound practices can coexist with sustained healthy runs of wild salmon.

Current Knowledge About the Effect of Hatcheries

Little is known about the interactions of hatchery and wild fish, but most scientists agree that hatcheries can complicate mixed stock fisheries and affect the genetics of wild fish stocks. Scientists do not agree on the degree such genetic changes will affect the fitness of wild stocks or if long-term fitness will be affected at all. Those who think that hatcheries negatively affect wild salmon generally agree that small-scale, strategically located facilities using local stocks will minimize the effects. Many biologists think that the biggest threat to wild fish occurs in areas where there are extremely

²⁹The policy, written in the form of regulations by the Oregon Fish and Wildlife Commission, is an enforceable standard of law.

large releases of hatchery fish that will compete with, predate upon, or mate with wild fish.

The lack of consensus among scientists results from a lack of data and research, but even where information exists, it is often subject to different interpretations. To complicate matters, results of specific studies may not be transferable to other areas or other salmon species, and year-to-year environmental changes may affect the results of these studies.

Genetic Ramifications

Scientific knowledge about the genetic impact on wild stocks of hatchery fish is still incomplete. Reduction in the fitness of salmon stocks, to the extent it has been documented, may involve numerous factors. Many studies report that hatchery fish are not as fit as wild fish both in juvenile residence in freshwater and during spawning. However, it is unknown if the long-term fitness of wild stocks will be affected, and some researchers think that observed reductions in hatchery fish may be the result of rearing conditions rather than genetics. Without baseline studies and adequate long-term monitoring, genetic changes are difficult to prove. Many researchers have noted a lack of emphasis in genetic studies, especially those that compare hatchery fish to wild fish. For many areas, including Alaska, not all significant wild stocks have been identified.

Scientists assume that wild stocks are the best suited to their stream of origin. Because many traits are thought to be inherited, biologists fear that hybrids will be less able to compete, less resistant to disease, and more vulnerable to predation. Such traits as egg size (evolved to reflect local conditions of stream substrate) and temperature tolerance are thought to be inherited. Some geneticists speculate that the homing ability of salmon may be a heritable quality. Thus, it may be important to keep hatchery salmon as genetically similar to local wild salmon as possible, and the practice of transporting brood stock even within a region may be detrimental. Additionally, the location of hatcheries where enhanced fish can easily stray to native streams may be detrimental to wild stocks (hatchery fish appear to be more likely to stray than wild fish).

Studies of hatchery salmon that measure genetic variability by average heterozygosity fail to show a significant loss of variability. The average heterozygosity of Japanese salmon, however, is below the U.S. average and this may indicate a loss of variability. Additionally, inbreeding has resulted in a reduction of variability for some other hatchery salmonids.

To complicate matters, some scientists doubt that hatcheries cause a loss in fitness of wild salmon. Some speculate that hatchery salmon could add variability to some wild salmon stocks.

Over-harvest of Wild Stocks

There is a general consensus among scientists that large-scale releases of hatchery salmon endanger wild stocks when returning hatchery fish are harvested in mixed stock fisheries with wild salmon. Some speculate that wild fish may be chemically attracted to hatchery fish and therefore school with them. Almost all Alaska fisheries had some degree of mixed stocks even before current hatcheries began operation. Smaller stocks are always in danger of depletion in mixed stock fisheries because there is a tendency to optimally harvest the larger stocks before they lose commercial quality at the terminal fisheries.

Competition

Some scientists suspect that the carrying capacity of freshwater rearing areas, nearshore waters, and on the high seas for salmon may be exceeded by the large-scale releases of hatchery salmon. A reduction in the average size of salmon has been reported throughout the Pacific, but various factors may be responsible. Some researchers believe ocean conditions affect the size of salmon more than competition. Much evidence, however, supports the theory of density-dependent growth for some salmon species during their rearing in freshwater. Some researchers also suggest that density-dependent growth occurs in estuaries, nearshore areas and in the ocean. Several studies suggest that density-dependent growth of sockeye and pink salmon occurs in the Gulf of Alaska.

Predation

Much is unknown about predation by hatchery salmon, but the greatest potential danger appears to be from the release of large numbers of coho smolts. There is speculation that large releases of hatchery fry may attract wild coho that will also feed upon wild fry.

Disease

Few studies document the transmittal of diseases between hatchery and wild salmon and there is no documentation of such transmittal in Alaska. Where transmittal of a disease by hatchery salmon has been documented, it occurred after fish were transplanted long distances. Hatchery fish appear to be more vulnerable to disease than wild fish because of the stress of hatchery conditions and large concentrations of eggs and fry.

Other Effects

Hatcheries may affect wild stocks in several other ways. Late-spawning hatchery strays may disturb the redds of wild fish. In the Pacific Northwest, there is some concern that unsuccessful hatcheries are resulting in a net drain when they use brood stock from depleted wild stocks. In the future, the use of salmon genetically altered to provide certain characteristics may affect

wild stocks. Lastly, the long-term effects of millions of unharvested hatchery pink salmon is unknown.

Tasks for the Future

Many tasks face scientists, managers, and policy makers during the coming decade. Such challenges include setting research priorities, minimizing possible impacts, and reviewing current practices and policies.

Setting Research Priorities

A major challenge for the next decade will be to obtain a consensus about research priorities concerning the interaction of hatchery and wild fish in Alaska. Coordination of studies among university researchers, commercial fisheries managers, federal and state government scientists, hatchery personnel, and fishermen may also be useful.

The current lack of knowledge includes an absence of information about a variety of issues: the degree that wild stocks school with hatchery fish, migration patterns of wild and hatchery fish, the percentage of hatchery and wild fish that stray, the reproductive success of these strays, the carrying capacity of marine and freshwater environments, harvest alternatives for mixed stock fisheries, ways to emulate mating behavior of wild salmon in a hatchery setting, cryopreservation techniques for eggs and embryos, and the effects of large-scale escapement of hatchery salmon. Without a better inventory of significant wild stocks and constant monitoring of their fitness, the long-term effects of enhancement may not be known until it is too late to correct them. Cataloguing genetic characteristics of significant stocks will provide baseline data for future study of the effects of hatchery salmon. Better knowledge in these areas will permit policy makers to make informed decisions and to consider the risks associated with various decisions.

Minimizing Impacts

Although the effects of hatcheries on wild fish are uncertain, the risk of such effects warrant a cautious approach. Rather than more studies, Hindar et al. (1991) think that the current knowledge of the effects of cultured fish on wild fish is enough to call for immediate action. The authors cite recommendations from symposiums on this subject. Practices that will reduce such impacts include siting hatcheries where hatchery fish will have minimal opportunities to interact with wild fish as well as specific prescriptions that will keep hatchery fish as genetically similar to wild fish as possible.

Senator Jones
September 11, 1991
Page 28

Reviewing Current Practices and Policies

Some fishery specialists recommend approval of new or expanded hatchery operations on a case-by-case basis only after a thorough examination of possible effects. Many researchers emphasize that hatcheries should strive for an optimum annual production rather than maximum production. Others suggest that further expansion of hatchery programs be delayed until more is known about their effects (Mathisen 1991). Hilborn (1990) recommends that there be a moratorium on the construction of new hatcheries and that hatcheries that cause adverse impacts on wild fish be closed.

Alaska statutes, ADF&G regulations and department policies contain many procedures to protect wild stocks. However, we were unable to locate any thorough studies that evaluate how well the current hatchery program protects wild salmon from possible negative effects of hatchery salmon. Such a review would help policy makers determine the risk of various alternatives for the future of Alaska's hatchery program.

I hope this information is useful. If you have any questions or want additional information, please contact this agency.

Attachments

REFERENCES

- ADF&G. 1982. "Policies and Procedures for the Private Nonprofit Hatchery Program and Regional Comprehensive Salmon Planning (Draft)." Alaska Department of Fish and Game, Division of FRED.
- ADF&G. 1985. "Alaska Department of Fish and Game Genetic Policy." Genetic Policy Review Team. Alaska Department of Fish and Game.
- ADF&G. 1986. "Selected Alaska Statutes and Regulations for Private Nonprofit Salmon Hatcheries." Alaska Department of Fish and Game, FRED Division.
- Alaska Finfish Farming Task Force. 1990. "Report to the Alaska Legislature." Juneau.
- Allendorf, F.W. 1991. "Effects of Genetic Changes in Enhanced Stocks on Productivity of Wild and Enhanced Salmonid Populations." Abstract from a paper presented at symposium, International Symposium on Biological Interactions of Enhanced and Wild Salmonids, p. 17, 17-20 June, at Pacific Biological Station, Nanaimo, British Columbia.
- Bams, R.A. 1976. "Survival and Propensity for Homing as Affected by Presence or Absence of Locally Adapted Paternal Genes in Tow Transplanted Populations of Pink Salmon (*Oncorhynchus gorbuscha*)." *Canadian Journal of Fisheries Aquatic Science* Vol. 33: 2716-2725.
- Beall, E.P. and M. Heland. 1991. "The Influence of Introduced Coho Salmon (*Oncorhynchus kisutch*) Juveniles on the Survival, Growth, Distribution, and Production of Atlantic Salmon (*Salmo salar*) Fry and Parr." Abstract from a paper presented at symposium, International Symposium on Biological Interactions of Enhanced and Wild Salmonids, p. 35, 17-20 June, at Pacific Biological Station, Nanaimo, British Columbia.
- Beamish, R.J. and B.L. Thomson. 1991. "Survival of Hatchery-Reared Salmon in the Strait of Georgia." Abstract from a paper presented at symposium, International Symposium on Biological Interactions of Enhanced and Wild Salmonids, 17-20 June, at Pacific Biological Station, Nanaimo, British Columbia.
- Bragg, John. 1990. "The Conooks are Coming." *Pacific Fishing*. December 38-39.
- CAA. 1990. "Fish Smuggling Becoming Big Business." *California Aquatic Farming*. California Aquaculture Association. October 1990.

- Chebanov, N.A. 1991. "Experimental Assessment of Genetic Aberrations in Hatchery Salmon and Recommended Procedures for Reducing Their Occurrence." Abstract from a paper presented at symposium, International Symposium on Biological Interactions of Enhanced and Wild Salmonids, p. 19, 17-20 June, at Pacific Biological Station, Nanaimo, British Columbia.
- Chettleburgh, Peter. 1991. "Notebook." *Northern Aquaculture*.
- Campton, Donald. 1991. "Genetic Contribution of Hatchery Steelhead to Wild Populations." Abstract of a poster presentation at symposium, Genetic Conservation of Salmonid Fishes, 24 June - 5 July, at Moscow, Idaho, and Pullman, Washington.
- Corley-Smith, Graham, Kanji Tsumura, Mark Siemens, Godin Teresa, and Edward Donaldson. 1991. "Preservation of Wild Stocks by Triploid Sterilization of Introduced Brook Trout." Abstract of a poster presentation at symposium, Genetic Conservation of Salmonid Fishes, 24 June - 5 July, at Moscow, Idaho, and Pullman, Washington.
- Cramer, S.P. 1991. "Dynamics of the Decline in Wild Coho (*Oncorhynchus kisutch*) Populations in the Lower Columbia River." Abstract from a paper presented at symposium, International Symposium on Biological Interactions of Enhanced and Wild Salmonids, p. 38, 17-20 June, at Pacific Biological Station, Nanaimo, British Columbia.
- Davis, Bob and Bob Burkett. 1989. "Background of the Genetic Policy of the Alaska Department of Fish and Game." Alaska Department of Fish and Game.
- Eriksson, C. and T. Eriksson. 1991. "Delayed Release of Baltic Salmon: Survival, Migration, and Management Implications." Abstract from a poster presented at symposium, International Symposium on Biological Interactions of Enhanced and Wild Salmonids, p. 53, 17-20 June, at Pacific Biological Station, Nanaimo, British Columbia.
- FFTF. 1990. "Alaska Finfish Farming Task Force: Report to the Legislature."
- Fleming, I.A. and M.A. Gross. 1991. "Breeding Competition and Reproductive Success in Hatchery Versus Wild Coho Salmon (*Oncorhynchus kisutch*)." Abstract from a poster presented at symposium, International Symposium on Biological Interactions of Enhanced and Wild Salmonids, p. 54, 17-20 June, at Pacific Biological Station, Nanaimo, British Columbia.
- Francis, R.C. and R.D. Brodeus. 1991. "Production and Management of Coho Salmon (*Oncorhynchus kisutch*): a Simulations Model Incorporating Environmental Variability." Abstract from a paper presented at symposium, International Symposium on Biological Interactions of Enhanced and Wild Salmonids, p. 41, 17-20 June, at Pacific Biological Station, Nanaimo, British Columbia.
- Fresh, K.L., S.L. Schroder, and M.I. Carr. 1991. "Predation by Northern Squawfish (*Ptychocheilus oregonensis*) on Hatchery and Wild Coho Salmon Juveniles (*Oncorhynchus kisutch*) in the Chehalis River, Washington." Abstract from a poster presented at symposium, International Symposium on Biological Interactions of Enhanced and Wild Salmonids, p. 55, 17-20 June, at Pacific Biological Station, Nanaimo, British Columbia.

- Fryer, J.K. and M. Schwartzberg. 1991. "Identification of Hatchery and Naturally Spawning Stocks of Columbia Basin Spring Chinook Salmon (*Oncorhynchus tshawytscha*) Using Scale Pattern Analyses." Abstract from a poster presented at symposium, International Symposium on Biological Interactions of Enhanced and Wild Salmonids, p. 57, 17-20 June, at Pacific Biological Station, Nanaimo, British Columbia.
- Gausen, Dagfinn. 1991. "The Norwegian Gene Bank Programme for Atlantic Salmon (*Salmo salar*)." Abstract of an oral presentation at symposium, Genetic Conservation of Salmonid Fishes, 24 June - 5 July, at Moscow, Idaho, and Pullman, Washington.
- Gausen, D. and V. Moen. 1991. "Large-scale Escapes of Farmed Atlantic Salmon (*Salmo Salar*) into Norwegian Rivers Threaten Natural Populations." *Canadian Journal of Fisheries Aquatic Science* Vol 48: 426-428.
- Gay, Joel. 1991. "Growing Fish: the Future of Alaska's Hatcheries." *Pacific Fishing*. March: 60-68.
- Geiger, H.J., J.A. Brady, D.M. Gaudet, S. McGeem and L. Peltz. 1991. "The Management of the Alaskan Salmon Hatchery Commercial Harvest." Abstract from a paper presented at symposium, International Symposium on Biological Interactions of Enhanced and Wild Salmonids, 17-20 June, at Pacific Biological Station, Nanaimo, British Columbia.
- Gharrett, A.J.; S. Lane, A.J. McGregor, and S.G. Taylor. 1991. "Use of a Genetic Marker to Examine Genetic Interaction among Subpopulations of Pink Salmon (*Oncorhynchus gorbuscha*)." Abstract from a paper presented at symposium, International Symposium on Biological Interactions of Enhanced and Wild Salmonids, 17-20 June, p. 20, at Pacific Biological Station, Nanaimo, British Columbia.
- Gritsenko, O.F. 1991. "Populations Structure of Sakhalin Pink Salmon (*Oncorhynchus gorbuscha*)." Abstract from a poster presented at symposium, International Symposium on Biological Interactions of Enhanced and Wild Salmonids, p. 58, 17-20 June, at Pacific Biological Station, Nanaimo, British Columbia.
- Gritsenko, O.F. and A.A. Kovtun. 1991. "Interaction Between Wild and Hatchery-Reared Chum Salmon (*Oncorhynchus keta*) from the Tym River." Abstract from a paper presented at symposium, International Symposium on Biological Interactions of Enhanced and Wild Salmonids, p. 26, 17-20 June, at Pacific Biological Station, Nanaimo, British Columbia.
- Hard, J. and W.R. Heard. 1991. "Homing and Straying in Two Stocks of Transplanted Chinook Salmon (*Oncorhynchus tshawytscha*)." Abstract from a poster presented at symposium, International Symposium on Biological Interactions of Enhanced and Wild Salmonids, p. 60, 17-20 June, at Pacific Biological Station, Nanaimo, British Columbia.
- Hayashizaki, Ken-ichi and Ida Hitoshi. 1991. "Size Decrease of Chum Salmon, - *Oncorhynchus keta*, in Tohoku Districts, Japan." Abstract from a poster presented at symposium, International Symposium on Biological Interactions of Enhanced and Wild Salmonids, 17-20 June, p. 45, at Pacific Biological Station, Nanaimo, British Columbia.

- Helle, John. 1981. "Significance of the Stock Concept in Artificial Propagation of Salmonids in Alaska." *Canadian Journal of Fishery Aquatic Science* Vol. 38: 1665-1671.
- Helle, John. 1982. "Genetic Considerations in Management of Wild and Hatchery Stocks of Salmonids." *The Role of Hatcheries in the Management of Wild Salmonids: Proceedings of a Symposium*. p. 25-29, 21 February, Reno, Nevada.
- Helle, John. 1983. "Gene Banks for Wild Fish Stocks." *Proceedings of the Olympic Wild Fish Conference*, 23-25 June, p. 41-44, Port Angeles, Washington.
- Hilborn, Ray. 1990. "Hatcheries and the Future of Salmon in the Northwest." Unpublished manuscript.
- Hilborn, R., R.C. Francis, and S.R. Hare. 1991. "Hatchery and Wild Fish Production on the Columbia River." Abstract from a paper presented at symposium, International Symposium on Biological Interactions of Enhanced and Wild Salmonids, p. 14, 17-20 June, at Pacific Biological Station, Nanaimo, British Columbia.
- Hindar, Kjetil, Nils Ryman and Fred Utter. 1991. "Genetic Effects of Cultured Fish on Natural Fish Populations." *Canadian Journal of Fisheries Aquatic Science* Vol. 48: 945-957.
- Irvine, J.R., R.E. Bailey, and R.C. Bocking. 1991. "Variability in Freshwater Survivals of Outplanted Coho Salmon (*Oncorhynchus kisutch*) in the Trent River, British Columbia, and a Preliminary Comparison Between the Marine Survivals of these Fish and Wild Trent River Coho." Abstract from a poster presented at symposium, International Symposium on Biological Interactions of Enhanced and Wild Salmonids, p. 62, 17-20 June, at Pacific Biological Station, Nanaimo, British Columbia.
- Ivankov, V.N. and I.N. Volkov. 1991. "Dynamics of Downstream Migration and Survival of Juvenile Salmon during Early Marine Life." Abstract from a poster presented at symposium, International Symposium on Biological Interactions of Enhanced and Wild Salmonids, p. 64, 17-20 June, at Pacific Biological Station, Nanaimo, British Columbia.
- Kaeriyama, Masahide. 1991. "Production Trends of Salmon Enhancement in Japan." Abstract from a paper presented at symposium, International Symposium on Biological Interactions of Enhanced and Wild Salmonids, p. 11, 17-20 June, at Pacific Biological Station, Nanaimo, British Columbia.
- Kapuscinski, A.R. and E.M. Hallerman. 1990. "AFS Position Statement: Transgenic Fishes." *Fisheries* Vol. 15 (4): 2-4.
- Karpenko, V.I. 1991. "The Role of Early Marine Life in the Production of Pacific Salmon." Abstract from a paper presented at symposium, International Symposium on Biological Interactions of Enhanced and Wild Salmonids, p. 29, 17-20 June, at Pacific Biological Station, Nanaimo, British Columbia.

- Kawamura, Hiroshi. 1991. "Stock Enhancement of Masu Salmon (*Oncorhynchus masu*) with Hatchery-Reared Fish and Difference in Timing of Smolting between Hatchery and Wild Populations in Hokkaido, Japan." Abstract from a paper presented at symposium, International Symposium on Biological Interactions of Enhanced and Wild Salmonids, p. 24, 17-20 June, at Pacific Biological Station, Nanaimo, British Columbia.
- Kelly, Michael, William Wilson, Patricia McMillan, and William Smoker. 1989. "Interactions Between Wild and Hatchery-Produced Salmon in Northwest North America, and Issues and Concerns over Sikusuikaq Springs Hatchery on the Noatak River, Alaska." Arctic Environmental Information and Data Center, University of Alaska Anchorage for the U.S. National Park Service. Cooperative Agreement No. CA-9700-5-8016.
- Khorevin, L.D. 1991. "Biological Monitoring of Artificially Propagated Chum Populations of Sakhalin Island." Abstract from a poster presented at symposium, International Symposium on Biological Interactions of Enhanced and Wild Salmonids, p. 66, 17-20 June, at Pacific Biological Station, Nanaimo, British Columbia.
- Kitchell, J.F. 1991. "Salmon in the Great Lakes: a Compromised Miracle." Abstract from a paper presented at symposium, International Symposium on Biological Interactions of Enhanced and Wild Salmonids, p. 28, 17-20 June, at Pacific Biological Station, Nanaimo, British Columbia.
- Krueger, Charles, Anthony Gharrett, Terrence Dehring, and Fred Allendorf. 1981. "Genetic Aspects of Fisheries Rehabilitation Programs." *Canadian Journal of Fisheries Aquatic Science* Vol. 38.
- Larkin, P.A. 1981. "A Perspective on Population Genetics and Salmon Management." *Canadian Journal of Fisheries Aquatic Science* Vol. 38: 1469-1475.
- Lichatowich, James and John McIntyre. 1987. "Use of Hatcheries in the Management of Pacific Anadromous Salmonids." *American Fisheries Society Symposium* Vol. 1: 131-136.
- Maitland, P.S., H.A. Reiger, G. Power, and N.A. Nilsson. 1981. "A Wild Salmon, Trout, and Char Watch: An International Strategy for Salmonid Conservation." *Canadian Journal of Fisheries Aquatic Science* Vol. 38: 1882-1888.
- Mathisen, Ole. 1991. Letter to Representative Fran Ulmer. Director of the Juneau Center for Fisheries and Ocean Sciences, University of Alaska. 24 June.
- McAllister, C.D. and C.D. Levings. 1991. "Evidence of Habitat Limitations for Hatchery and Wild Chinook Salmon (*Oncorhynchus tshawytscha*) in Two British Columbia Estuaries." Abstract from a paper presented at symposium, International Symposium on Biological Interactions of Enhanced and Wild Salmonids, p. 34, 17-20 June, at Pacific Biological Station, Nanaimo, British Columbia.
- Menke, Kathleen. 1990. "In Danger of Diluting the Salmon Gene Pool." *Pacific Fishing*. December: 46-50.
- Miller, Dirk. 1991. "Record Year for Pinks?" *Juneau Empire* August 23. p. 1.

- Nehlen, Willa, Jack Williams, and Lichatowich. 1991. "Pacific Salmon at the Crossroads: Stocks at Risk from California, Oregon, Idaho, and Washington." *Fisheries* Vol. 16 (2): 4-21.
- Oregon. 1990. "Oregon's Wild Fish Management Policy: What is it and What Does it do?" Unpublished briefing paper.
- Peltz, L., D. Eggers, B. Barrett, B. Bue, N. Dudiak, M. Johnson, S. Sharr, L. White, and H. Yuen. 1991. "Trends in Abundance of Hatchery and Wild Stocks of Pink Salmon (*Oncorhynchus gorbuscha*) in Kodiak Island, Lower Cook Inlet, and Prince William Sound, Alaska." Abstract from a paper presented at symposium, International Symposium on Biological Interactions of Enhanced and Wild Salmonids, 17-20 June, at Pacific Biological Station, Nanaimo, British Columbia.
- Peterman, Randall M. 1984. "Density-Dependent Growth in Early Ocean Life of Sockeye Salmon (*Oncorhynchus nerka*)." *Canadian Journal of Fisheries and Aquatic Sciences* Vol. 41: 20-27.
- Reimers, Paul. 1979. "Success in a Hatchery Program with Fall Chinook Salmon by Simulating the Natural Life History of the Stock." *The Progressive Fish-Culturist* Vol. 41 (4): 192-195.
- Reisenbichler, R.R. and J.D. McIntyre. 1977. "Genetic Differences in Growth and Survival of Juvenile Hatchery and Wild Steelhead Trout (*Salmo gairdneri*)." *Journal Fisheries Research Board of Canada* Vol. 34: 123-128.
- Ricker, W.E. 1981. "Changes in the Average Size and Average Age of Pacific Salmon." *Canadian Journal of Fisheries and Aquatic Sciences* Vol. 38: 1636-1656.
- Riddell, B., R. Withler, T. Carter, and D. Tuck. 1991. "Realized Heritability of Size at Maturity in Coho (*Oncorhynchus kisutch*) Salmon." Abstract from a poster presented at symposium, International Symposium on Biological Interactions of Enhanced and Wild Salmonids, p. 69a, 17-20 June, at Pacific Biological Station, Nanaimo, British Columbia.
- Ryman, Nils and Gunnar Stahl. 1981. "Genetic Perspectives of the Identification and Conservation of Scandinavian Stocks of Fish." *Canadian Journal of Fisheries and Aquatic Sciences* Vol. 38: 1562-1575.
- Seeb, Jim. 1991. Principal Geneticist for the Alaska Department of Fish and Game. Letter to Commissioner Carl Rosier. 19 August.
- Seiler, D., L. Lestelle, S. Meadows, G. Blair, S. Chitwood, and S. Neuhauser. 1991. "Supplementation of Wild Coho Salmon (*Oncorhynchus kisutch*) with Hatchery-Produced Fry in Washington Coastal Streams." Abstract from a paper presented at symposium, International Symposium on Biological Interactions of Enhanced and Wild Salmonids, p. 36, 17-20 June, at Pacific Biological Station, Nanaimo, British Columbia.

- Shrimpton, J.M., N.J. Bernier, G.K. Iwama, and D.J. Randall. 1991. "Osmoregulatory Ability in Sea Water in Smolting Hatchery and Wild Coho Salmon (*Oncorhynchus kisutch*). Abstract from a poster presented at symposium, International Symposium on Biological Interactions of Enhanced and Wild Salmonids, p. 71, 17-20 June, at Pacific Biological Station, Nanaimo, British Columbia.
- Shubin, A.O. and V.E. Kaevo. 1991. "The Influence of a Pink Salmon (*Oncorhynchus gorbuscha*) Hatchery on Natural Pink Salmon Production in the Ochepukha River, Sakhalin." Abstract from a poster presented at symposium, International Symposium on Biological Interactions of Enhanced and Wild Salmonids, p. 72, 17-20 June, at Pacific Biological Station, Nanaimo, British Columbia.
- Skaala, O., K.E. Jorstad, and R. Borgstrom. 1991. "Genetic Impact on Wild Populations from Fish Farming: Experiments with Genetically Tagged Brown Trout (*Salmo trutta* L.)." Abstract from a paper presented at symposium, International Symposium on Biological Interactions of Enhanced and Wild Salmonids, 17-20 June, at Pacific Biological Station, Nanaimo, British Columbia.
- Smoker, William. 1985. "Review of Literature on Impacts of Salmon Hatcheries in Alaska." Final Report to the University of Alaska, Juneau, Research Council. School of Fisheries and Science. Juneau.
- Steer, J., P.J. Starr, E.A. Perry, and K.D. Hyatt. 1991. "Trends in Biological Characteristics and Survival Rates of Wild and Enhanced Salmonids in British Columbia." Abstract from a paper presented at symposium, International Symposium on Biological Interactions of Enhanced and Wild Salmonids, p. 13, 17-20 June, at Pacific Biological Station, Nanaimo, British Columbia.
- Swain, D.P. and B.E. Riddell. 1991. "Quantitative Genetic Variation for Morphology in Hatchery and Wild Populations of Coho Salmon (*Oncorhynchus kisutch*)." Abstract from a poster presented at symposium, International Symposium on Biological Interactions of Enhanced and Wild Salmonids, p. 74, 17-20 June, at Pacific Biological Station, Nanaimo, British Columbia.
- Thorgaard, Gary and Joseph Cloud. 1991. "Reconstitution of Genetic Strains of Fish using Androgenesis and Chimeras." Abstract of an oral presentation at symposium, Genetic Conservation of Salmonid Fishes, 24 June - 5 July, at Moscow Idaho and Pullman, Washington.
- Thompkins, A. 1991. "Responses of Wild and Hatchery Chum Fry (*Oncorhynchus keta*) to Risk of Predation." Abstract from a poster presented at symposium, International Symposium on Biological Interactions of Enhanced and Wild Salmonids, p. 77, 17-20 June, at Pacific Biological Station, Nanaimo, British Columbia.
- Ward, B.R., P.A. Slaney, and A.F. Tautz. 1991. "Differential Survival and Synchronous Return from the Sea in Keogh River Wild and Hatchery Steelhead (*Oncorhynchus mykiss*)." Abstract from a paper presented at symposium, International Symposium on Biological Interactions of Enhanced and Wild Salmonids, p. 42, 17-20 June, at Pacific Biological Station, Nanaimo, British Columbia.

- Wampler, P.T., J.D. Anderson, E.E. and Knudsen. 1991. "Evaluation of Planting Native Hatchery Coho Fry into Streams Containing Wild Coho Fry." Abstract from a poster presented at symposium, International Symposium on Biological Interactions of Enhanced and Wild Salmonids, p. 79, 17-20 June, at Pacific Biological Station, Nanaimo, British Columbia.
- Waples, Robin, Gary Winans, Fred Utter, and Conrad Mahnken. 1990. "Genetic Approaches to the Management of Pacific Salmon." *Fisheries* Vol. 15 (5): 19-25.
- Whelan, K.F. and P. McGinnity. 1991. "A Comparative Biological and Genetic Profile of Wild and Ranched Atlantic Salmon (*Salmo salar*) Stocks from the Burrishoole System, Co. Mayo, Western Ireland." Abstract from a paper presented at symposium, International Symposium on Biological Interactions of Enhanced and Wild Salmonids, p. 15, 17-20 June, at Pacific Biological Station, Nanaimo, British Columbia.
- Wildt, David and William Rall. 1991. "Strategies for Collecting, Cryopreserving and Using Germplasm and Embryos from Wildlife Species." Abstract of an oral presentation at symposium, Genetic Conservation of Salmonid Fishes, 24 June - 5 July, at Moscow, Idaho, and Pullman, Washington.
- Wood, C.C., K.D. Hyatt, D. Boisclair, E.W. Carter, and B. Emmett. 1991. "Testing for Ecological Interactions between Wild and Hatchery-Reared Salmonids as an Explanation for Declining Smolt-to-Adult Survival in Sockeye Salmon (*Oncorhynchus nerka*) Populations of Barkley Sound, Vancouver Island." Abstract from a paper presented at symposium, International Symposium on Biological Interactions of Enhanced and Wild Salmonids, p. 32, 17-20 June, at Pacific Biological Station, Nanaimo, British Columbia.
- Zhivotovsky, L.A., V. Hramtsov, and M. Glubokovsky. 1991. "Population Dynamics in Pink Salmon (*Oncorhynchus gorbuscha*)." Abstract from a paper presented at symposium, International Symposium on Biological Interactions of Enhanced and Wild Salmonids, p. 21, 17-20 June, at Pacific Biological Station, Nanaimo, British Columbia.

PERSONAL COMMUNICATIONS

Burkett, Bob. Telephone interview. Division of Fisheries Rehabilitation, Enhancement and Development. September 1991. Juneau.

Duffy, Kevin. Telephone interview. Planning Coordinator for the Division of Fisheries Rehabilitation, Enhancement and Development. September 1991. Juneau.

Gharet, Tony. Telephone interview. Professor at the University of Alaska. September 1991. Juneau.

Mathisen, Ole. Personal interview. Director Juneau Center for Fisheries and Ocean Sciences, University of Alaska. August 1991. Juneau.

Seeb, Jim. Telephone conversations. Principal geneticist for the Division of Fisheries Rehabilitation, Enhancement and Development. September 1991. Anchorage.

Meyers, Ted. Telephone conversation. Fisheries pathologist for the Division of Fisheries Rehabilitation, Enhancement and Development. September 1991. Juneau.

Utermohle, George. Telephone conversation. Legislative counsel for the Legislative Affairs Agency. September 1991. Juneau.

Wertheimer, Alex. Telephone conversation. Biologist for the National Marine Fisheries Service, Auke Bay Laboratory. August 1991. Auke Bay.

White, Steve. Telephone conversation. Assistant attorney general for the Alaska Department of Law. September 1991. Juneau.

ATTACHMENT A
1975 Position Paper of the Alaska District of the
American Institute of Fishery Research Biologists

GENETIC CONSIDERATIONS IN
ARTIFICIAL PROPAGATION OF SALMONIDS

WHEREAS throughout North America there is an accelerating interest in artificial propagation as a means of supplementing our natural salmonid stocks, and an urgent need exists for special planning regarding genetic considerations in artificial propagation of salmonid fishes; and

WHEREAS need for genetic planning exists in all salmonid enhancement programs in North America; and

WHEREAS it is desirable to maintain existing wild stocks in concert with artificially propagated stocks through:

- (1) location of sites for artificial propagation with regard to indigenous wild stocks, so that the adaptive genetic diversity of wild stocks will not be lost or diluted by chance interbreeding with cultured stocks,
- (2) management of fishing pressure so as not to endanger reproduction of wild stocks,
- (3) recognition of the potential behavioral and genetic stresses on native fishes caused by transplant stocks; and

WHEREAS it is also desirable to maintain adaptive genetic diversity in most artificially propagated stocks through:

- (1) use of sufficient numbers of females and males in brood stock to avoid inbreeding depression problems,
- (2) avoidance of selective breeding except in special situations or when used as a research technique: Now, therefore, be it

RESOLVED, That enhancement or rehabilitation of salmonid stocks in a stream or lake system should utilize native stocks already present; and be it further

RESOLVED, That in special situations where no alternative to transplantation exists, the characteristics of the donor stock be carefully matched so as to be compatible with the new environment; and be it further

RESOLVED, That the biological impact of transplantation on stocks of fish present in the recipient and surrounding watersheds be thoroughly evaluated; and be it further

RESOLVED, That artificially propagated stocks should be isolated (in time and in space) from wild stocks to allow effective management of fishing pressure on both types; and be it further

RESOLVED, That all agencies involved in enhancement and management of wild and cultured stocks of salmonids evaluate their present policies with respect to conservation of genetic diversity in wild stocks; and be it further

RESOLVED, That copies of this resolution be forwarded to agencies involved in artificial propagation and enhancement of salmonid fishes.

RESOLUTION

AMERICAN FISHERIES SOCIETY

Presented at American Fisheries Society
Detroit, Michigan September 22, 1976

Genetic Considerations in Artificial Propagation of Fishes

WHEREAS throughout North America there is an accelerating interest in artificial propagation as a means of supplementing our natural stocks, and an urgent need exists for special planning regarding genetic considerations in artificial propagation of fishes; and

WHEREAS need for genetic planning exists in all fish enhancement programs in North America; and

WHEREAS it is desirable to maintain existing wild stocks in concert with artificially propagated stocks through:

- (1) location of sites for artificial propagation with regard to indigenous wild stocks, so that the adaptive genetic diversity of wild stocks will not be lost or diluted by chance interbreeding with cultured stocks,
- (2) management of fishing pressure so as not to endanger reproduction of wild stocks,
- (3) recognition of the potential behavioral and genetic stresses on native fishes caused by transplant stocks; and

WHEREAS it is also desirable to maintain adaptive genetic diversity in most artificially propagated stocks through:

- (1) use of sufficient numbers of females and males in brood stock to avoid inbreeding depression problems,
- (2) avoidance of deleterious selective breeding: Now, therefore be it

RESOLVED, That all agencies involved in enhancement and management of wild and cultured fish stocks evaluate their present policies and implement appropriate practices with respect to conservation of genetic diversity in wild stocks; and be it further

RESOLVED, That copies of this resolution be forwarded to all state, provincial, and federal agencies involved in artificial propagation and enhancement of fishes.

ATTACHMENT B
ADF&G Policies Relating to Hatcheries

Alaska Department of Fish & Game
GENETIC POLICY

by

Genetic Policy Review Team
Bob Davis - ADF&G, FRED, Chairman

Other Team Members:

Brian Allee - PWSAC, Cordova
Don Amend - SSRAA, Ketchikan
Bruce Bachen - NSRAA, Sitka
Bill Davidson - SJC, Sitka
Tony Gharrett - UAJ, Juneau
Scott Marshall - ADF&G, Comm. Fish
Alex Wertheimer - NMFS, Auke Bay Lab

Approved:



Don W. Collinsworth, Commissioner
Alaska Department of Fish and Game

Date: 6.11.85

INTRODUCTION

Alaska's valuable salmon industry relies on production from wild systems and, increasingly, on fish produced by aquaculture programs. The importance of maintaining healthy wild stocks and implementing successful enhancement activities underlies the need for an effective genetic policy. The genetic guidelines created to steer Alaska's aquaculture efforts were established in the mid-70's and have been reviewed to ensure that they reflect current knowledge, and goals. A revised genetic policy has been established that contains guidelines, supporting information and recommendations.

The genetic policy contains restrictions that will serve to protect the genetic integrity of important wild stocks. Certainly in Alaska where wild stocks are the mainstay of the commercial fishery economy, it is necessary to protect these stocks through careful consideration of the impacts of enhancement activities. Another important aspect of the genetic policy is the orientation towards increasing the productivity of enhancement programs in the state. Adherence to the guidelines will help maintain adequate genetic variability ensuring that the enhanced stock will be able to adapt to changing environmental conditions. The policy also includes considerations for selective breeding for desirable characteristics.

Due to the limited amount of information available on the genetic impacts of salmon enhancement on wild stocks, much of the basis for these guidelines is theoretical or based on work done with other species. Consequently, the most important considerations used in writing the guidelines are presented as a mechanism for illustrating the intent of the policy. An understanding of the rationale behind the policy is imperative to its effective application to individual cases under the very diverse conditions found in Alaska.

The importance of the genetic guidelines will continue to increase as aquaculture activities expand their production. This policy represents a consensus of opinion and should continue to be periodically reviewed to ensure that the guidelines are consistent with current knowledge. By doing so, we will be able to meet the goal of greater fish production through enhancement while maintaining healthy wild stocks.

POLICY STATEMENT

I. Stock Transport

- A. Interstate: Live salmonids, including gametes, will not be imported from sources outside the state. Exceptions may be allowed for trans-boundary rivers.
- B. Inter-regional: Stocks will not be transported between major geographic areas: Southeast, Kodiak Island, Prince William Sound, Cook Inlet, Bristol Bay, AYK and Interior.
- C. Regional: Acceptability of transport within regions will be judged on the following criteria.
 - 1. Phenotypic characteristics of the donor stock must be shown to be appropriate for the proposed fish culture regions and the goals set in the management plan.
 - 2. No distance is set or specified for transport within a region. It is recognized that transplants occurring over greater distances may result in increased straying and reduce the likelihood of a successful transplant. Although the risk of failure affects the agency transporting the fish, transplants with high probability of failure will be denied. Proposals for long distance transport should be accompanied by adequate justification for using nonlocal stock.

II. Protection of Wild Stocks

- A. Gene flow from hatchery fish straying and intermingling with wild stocks may have significant detrimental effects on wild stocks. First priority will be given to protection of wild stocks from possible harmful interactions with introduced stocks. Stocks cannot be introduced to sites where the introduced stock may have significant interaction or impact on significant or unique wild stocks.
- B. Significant or unique wild stocks must be identified on a regional and species basis so as to define sensitive and nonsensitive areas for movement of stocks.
- C. Stock Rehabilitation and Enhancement
 - 1. A watershed with a significant wild stock can only be stocked with progeny from the indigenous stocks.
 - 2. Gametes may be removed, placed in a hatchery, and subsequently returned to the donor system at the appropriate life history state (eyed egg, fry or fingerling). However, no more than one generation of separation from the donor system to stocking of the progeny will be allowed.
- D. Drainages should be established as wild stock sanctuaries on a regional and species basis. These sanctuaries will be areas in which no enhancement activity is permitted except gamete removal or broodstock development. Use of such reservoirs for broodstock development should be considered on a case-by-case basis, and sliding egg take removal schedules applied to such systems should be conservative.

- E. Fish releases at sites where no interaction with, or impact on significant or unique wild stocks will occur, and which are not for the purpose of developing, rehabilitation of, or enhancement of a stock (e.g., release for terminal harvest or in landlocked lakes) will not produce a detrimental genetic effect. Such releases need not be restricted by genetic concerns.

III. Maintenance of Genetic Variance

A. Genetic diversity among hatcheries

1. A single donor stock cannot be used to establish or contribute to more than three hatchery stocks.
2. Off-site releases for terminal harvest rather than development or enhancement of a stock need not be restricted by III.A.1, if such release sites are selected so that they do not impact significant wild stocks, wild stock sanctuaries, or other hatchery stocks.

B. Genetic diversity within hatcheries and from donor stocks

1. A minimum effective population (N_e) of 400 should be used for broodstock development and maintained in hatchery stocks. However, small population sizes may be unavoidable with chinook and steelhead.
2. To ensure all segments of the run have the opportunity to spawn, sliding egg take scales for donor stock transplants will not allocate more than 90% of any segment of the run for broodstock.

GUIDELINES AND JUSTIFICATIONS

I. Stock Transport

- A. Interstate: It is generally accepted that population of salmonids which have existed over many generations in a given watershed have evolved traits that make them best adapted for survival in that environment. The greater the distance that a population is transferred from its native environment or the greater the difference in environmental conditions between the donor and transplant stream, the less likely the genetic characteristics of the population will fit the new environment. If the fitness of the population is indeed reduced in the new environment, then the probability of the transplant succeeding would be affected. In addition, interbreeding of a transferred stock with indigenous stocks could transfer gene traits that would reduce the fitness of the native populations. In many states, discrete stocks cannot be identified because excessive movement and interbreeding have already occurred. The State of Alaska, therefore, desires to protect and develop local stocks by restricting the movement of live fish or eggs into the state. There are, however, several trans-boundary rivers penetrating British Columbia, Canada, that flow into the state of Alaska. In some instances, donors from these stocks might fit a well-designed management plan.
- B. Inter-regional: The environment can vary greatly from one region to another in a state as large as Alaska. For similar reasons given in I.A. above, the transfer of fish from one region to another is restricted. Consideration may be given to regional border areas, especially when no suitable donor stock is available within a region.

C. Regional: Although it is recognized that indigenous stocks are best for donor stock development, there have been numerous successful transplants, especially if the environment at the new site is similar to that of the donor stock and distance between the sites is not great. There is insufficient scientific data to predict how far or how diverse the environment must be before a negative impact will occur. However, it is believed that within a region site matching opportunities may be available. As site matching characteristics decrease and transplant distance increases within the regional borders greater justification is required for the proposed transplant. The following should be considered when selecting a donor stock:

1. Matching: Phenotypic characteristics of the donor stock should be matched to the environment at the site and to the management goals. Water chemistry and temperature profiles should be considered. Island stocks should be matched to other islands or to short rivers of comparable characteristics where possible. Time of spawning and fry emergence should be matched or compensated with the hatchery temperature required. Any deviations should be addressed and justified in the permit application or the annual management plan.
2. Migration Routes: The probable migration routes and potential user groups should be identified. The applicant must determine a probable migration route based on the migration route of the proposed stock and characteristics (topography) of the transplant site. Coded wire tagging of hatchery releases can determine the accuracy of migration route predictions as well as assess possible impact on local stocks.

II. Protection of Wild Stocks

A. Prevention of detrimental effects of gene flow from hatchery fish straying and interbreeding with wild fish.

Straying of hatchery fish released at the hatchery or off-station can potentially impact the fitness of wild fish populations through interbreeding of wild and hatchery fish. This assumes that hatchery and wild fish are adapted to different environments and either would presumably be less fit in the environment of the other and that hybrids would be less fit for either environment. Wild stocks have presumably been rigorously adapted to their native environment. Because of the large number of loci involved in the adaptation, many "successful" combinations of genetic information are possible along with the enormous number of "unsuccessful" combinations. Hybridization between discrete populations may produce a stock that has reduced fitness and therefore reduced production. Hatchery fish have been subjected to selection pressure for survival within artificial culture regimes, and may also have been originally derived from another stock adapted to totally different conditions than the impacted wild stock. Continued influx of hatchery fish together with the return of hybrids may alter the wild gene pool, reduce stock fitness, and thus threaten the survival of the wild population.

An alternative perspective is that hatchery strays will have little genetic impact on wild stocks. The influx of new genetic material through straying is a natural process in the development and expansion of salmon populations. If adaptation of the natural population is indeed very specific and selection is intense, then

selection will favor and maintain the genetic complex of the wild populations. If adaptation is less specific and less intensive, then the genetic impacts from gene flow are insignificant. It is true that some straying occurs among adjacent wild populations and in most cases has occurred for a long enough time that such populations are quite similar genetically. However, situations in which transplanted stocks are involved are not analogous, as transplanted stocks would be less similar and gene flow would have a more profound effect. It is also true that the impact of introgression into the wild gene pool of genes from fish transplanted from a radically different environment may be limited by natural selection. Again the situations of concern do not necessarily lie near this extreme; hybrids and strays may be fit enough to dilute or replace the wild genome. Inherent homeostatic mechanisms for gene expression may compensate for some genetic influx.

The magnitude of straying relative to the size of the wild run is the most important criterion, as massive spawning by hatchery strays may jeopardize a wild population by displacement on spawning habitat and superimposition of redds, as well as, genetic influx. A conservative management approach dictates avoiding release sites where large numbers of hatchery strays can be expected to interact with significant or unique wild stocks. This approach can be achieved by spatial or temporal isolation of the hatchery and wild stock.

B. Regional designation of significant and unique wild stocks.

The magnitude of salmon populations varies between watersheds from intermittent runs maintained by

straying to hundreds of thousands of fish. In evaluating the impacts of salmon enhancement projects, consideration must be given to the potential of detrimental effects from straying and intermingling with wild populations and possible resultant loss of wild production. Such consideration must take into account the benefits of the enhancement activity and the significance of the wild stocks impacted. Designation of criteria for runs of fish that are considered significant would greatly expedite the evaluation process. However, "significance" must be defined not only by the magnitude of the run, but also in the context of local importance and utilization. A small sockeye salmon stock near a village in southeast Alaska may be "significant", whereas the same size population may be too small to be considered a manageable entity in Bristol Bay. Because local utilization is an important concern, a regional planning group such as the Salmon Enhancement Regional Planning Teams, should consider what criteria will be used to determine significant stocks within a region and recommend such stock designations.

C. Stock rehabilitation and enhancement.

1. A watershed with significant wild stocks can only be stocked with progeny from the indigenous stocks. Rehabilitation of a watershed implies that there is insufficient production in habitat that formerly maintained a stock of some magnitude. Unless the indigenous stock has gone to extinction, use of an exogenous stock has potential for genetic damage noted in II.A. This damage will be exacerbated by the imprinting and homing of the transplanted stock to the impacted watershed, and potential displacement of wild

juveniles by the exotics stocked in the rearing habitat.

Enhancement of habitat not naturally accessible to salmon involves stocking eyed eggs, fry, or fingerlings, thus gaining production from this unutilized habitat. Where the inaccessible habitat is located above barriers on watersheds that maintain significant natural populations, stocking nonindigenous populations again has potential for genetic impacts noted in II.A., exacerbated by imprinting and homing of the transplanted stock to the watershed. For both rehabilitation and above barrier stockings, use of the indigenous stock alleviates these concerns.

2. When enhancing a stream using the indigenous stock, the fish used for stocking shall not be removed from the wild system to a hatchery for more than one generation.

Hatchery incubation and rearing select for a limited set of biological and behavioral traits which are not necessarily the most suitable for survival in the wild environment. Because of this potential for such selection, the transfer of hatchery fish to rehabilitate or enhance stocks in depleted or underutilized watersheds runs the risk of altering the genetic character of the wild stock, even if the indigenous stock was the original donor stock for hatchery population. By restricting the separation between the transfer to the hatchery and the stocking to no more than one generation (e.g., eggs taken in a given year are cultured to fry or fingerling release at the hatchery; eggs or fish from the returns to the

hatchery of this donor transplant are used for stocking), the risk of negative effects due to selection in the hatchery are minimized.

D. Establishment of wild stock sanctuaries.

As noted in preceding sections, there is concern that hatchery culture of salmon through their freshwater (and in some cases, initial estuarine) life history phases may select for a limited set of biological traits that are not suitable for wild populations. Loss of genetic variability through intensive inbreeding for domestication and desired traits has often resulted in detrimental genetic effects in agronomy and agriculture, such as reduced resistance to disease or adverse environmental conditions. Original wild strains can provide the genetic variability needed to outbreed domestics and alleviate inbreeding depression. Because there is potential for detrimental impacts due to reduction of genetic variability, there is a need to preserve a variety of wild types for future broodstock development and outbreeding for enhancement programs. Designation of watersheds where hatcheries or hatchery plants are not allowed would allow wild stocks within these watersheds to be subjected to natural selection only, within the life history phases cultured at hatcheries. These watersheds would be "gene banks" of wild-type genetic variability.

III. Maintenance of Genetic Variance

A. Genetic diversity among hatcheries.

There is general agreement that by introducing and maintaining a wide diversity of wild donor stock

populations into the hatchery system that the prospects for long term success of the hatchery program in Alaska will be enhanced. Diversity tends to buffer biological systems against disaster, either natural or man-made. Developing and maintaining hatchery broodstock from a wide variety of donors will buffer the hatchery system against future catastrophes. Agricultural crop production in the U. S. provides a prime example of the dangers of genetic uniformity.

In an effort to increase yield, plant breeders have come to rely on a few highly productive strains. In 1970 approximately 15% of the corn production in the United States was lost to corn blight. The corn blight responsible, a mutant of the normal blight causing fungus, did not attack all strains. Only one strain of corn was vulnerable, but that strain of corn was grown by nearly every farmer in the country. Breeders were able to recover from the corn blight epidemic by replacing Texas cytoplasm with normal cytoplasm. Recovery was rapid because adequate genetic variability was available. There are other examples.

How does this relate to salmonid culture? Salmonid stocks apparently differ in levels of disease resistance, temperature tolerance, acid tolerance, and in their response to artificial selection. It seems imprudent to assume that conditions similar to those found in agriculture will not occur in aquaculture. In addition, the ability to genetically improve hatchery broodstock performance in the future will depend on the availability of genetic variability such as is found among wild salmonid stocks. A hatchery system with a variety of diverse broodstocks will be a valuable resource.

Genetic diversity does not guarantee protection from disaster, but uniformity seems to invite catastrophe. Local failures are inevitable within the hatchery system. It seems prudent to provide the system with a level of insurance by developing and preserving diversity among hatcheries.

Off-site releases for terminal harvest, whether for the commercial fishery or for a put and take sport fishery should have no adverse genetic effect if they are released at sites selected so that they do not impact significant wild stocks, wild stock sanctuaries or other hatchery stocks. The success of this type of release from a genetic standpoint depends on the ability to manage and harvest the return. If returns can not be harvested, increased straying may result which might lead to an impact on wild stocks at a greater than expected distance from the release site.

B. Genetic diversity within hatcheries and from donor stocks.

There is a general consensus among geneticists that fitness (reproductive potential) is enhanced by heterozygosity (genetic variability). Any loss of genetic variation will be accompanied by a concomitant reduction in fitness. Genetic variation allows a population to adapt to a changing environment or to adapt to and colonize a new environment. Available genetic variation determines how rapidly a population will respond to either artificial or natural selection. On the other hand, selection, inbreeding and random genetic drift will reduce genetic variability in a population.

Natural selection, that is selection for fitness, is a continuing process and should not be so intense that it

has a significant effect in reduction of genetic variation, unless the population is in a new and quite different environment. Artificial selection on the other hand can be very intense, but can either be avoided or designed to assure that possible negative effects to fitness are offset by increased production efficiency due to the selection program, and by more efficient culture techniques. Inbreeding due to the deliberate mating of related individuals can be easily avoided in salmon hatcheries. Undoubtedly, in hatcheries and possibly in natural stocks the most important cause of loss of genetic variation is random genetic drift. In hatcheries reduction of genetic variation caused by inbreeding and genetic drift can easily be avoided by using adequate numbers of spawners.

Random genetic drift in general refers to fluctuations in gene frequency that occur as a result of chance. Such fluctuations occur, especially in small populations, as a result of random sampling among gametes. The amount of change but not the direction of change, can be predicted. The rate of this change is related inversely to effective population size (N_e). The smaller the effective population size the greater the fluctuation in gene frequencies. In small populations random genetic drift can result in inadvertent loss of genetic variability which may significantly reduce the fitness of the population.

Effective population size (N_e) is defined as the size of an idealized population that would lose genetic variability at the same rate as the sample population. An idealized population is one in which there is no

mutation or selection, there are equal numbers of males and females, mating is random, etc. Obviously it is very unlikely that any natural population will meet all criteria for an idealized population.

Breeding structure of a population can profoundly affect the rate at which genetic variability is lost. However, we can determine the effective breeding size (N_e) for breeding structures and obtain the rate of inbreeding (ΔF) as

$$\Delta F = 1/2N_e$$

so the consequences of breeding structure can be related to the loss of variation.

Many breeding structure variations can influence the effective population size. Four seem likely to operate in a salmon hatchery population: (1) numbers of males and females in the breeding population; (2) unequal numbers in successive generations; (3) nonrandom distribution of offspring among families; and (4) overlapping generations. These are discussed in greater detail in Appendix A.

Any of these variations in breeding structure may have a marked effect on N_e . Although it may be impossible to control or even to measure variation in family size it is important to keep in mind the relationship to effective population size. Breeding plans that would aggravate or increase the variation of family size should be avoided. The effect of overlapping populations is to increase the effective population number, in that individuals mating in different years contribute to greater diversity. For example, it would

take a larger number of pink salmon each year to maintain $N_e = 400$ than it would sockeye salmon.

The factor having the greatest potential effect in the hatchery and over which we have most control is sex ratio. As the formula indicates (Appendix A) the effective population size is affected most by the numbers of the least frequent sex. It is important to consider this in the breeding plan. In salmon, because a male can be used to fertilize the eggs of a large number of females, there is a temptation to do so. This temptation should be moderated by the necessity to maintain an effective population size which will assure that adequate genetic variation is maintained in the population. A minimum effective population (N_e) of 400 should be maintained. At this size the rate of inbreeding will be 0.125 percent per generation which should not have a significant effect on the long term fitness of the population.

In some cases, for example with chinook and steelhead, small population size may be unavoidable. In such cases a plan should be developed to offset the effects of small population size by infusion of genes from a source outside the hatchery population, such as the original donor source. Help in designing these breeding plans can be obtained from the Principal Geneticist, FRED Division, Alaska Department of Fish and Game.

While developing hatchery stocks from wild donor sources it is important that the genetic variability in the donor stock be protected. Cropping of the early or late run segments of a donor stock can change the timing of that run, which will reduce genetic variability of the population and may be detrimental to the stock's prospects for long term survival. To prevent